Proceedings of the 2006 Trinational Pacific Sardine Forum

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PROCEEDINGS OF THE 2006 TRINATIONAL PACIFIC SARDINE FORUM

by

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ABSTRACT

Hrabok, C., Schweigert, J.F., Chalmers, D., and Pepper, D. 2007. Proceedings of the 2006 Trinational Pacific sardine forum. Can. Manuscr. Rep. Fish. Aquatic. Sci. 2809: v + 74 p.

The 7th annual Trinational Pacific sardine forum was held in Vancouver, B.C. bringing together scientists, managers, and the fishing industry from Mexico, the United States, and Canada to share information and research findings related to the sardine resource throughout the west coast of North America. Working groups discussed: 1) current stock status and assessment plans for the coming season, 2) stock identification results and planned or ongoing research projects, 3) industry issues and concerns. Fishery managers provided updates on the landings from the last season and any anticipated changes in the coming year. Results of research studies were presented in two scientific sessions.

RÉSUMÉ

Hrabok, C., Schweigert, J.F., Chalmers, D., and Pepper, D. 2007. Proceedings of the 2006 Trinational Pacific sardine forum. Can. Manuscr. Rep. Fish. Aquatic. Sci. 2809: v + 74 p.

Le 7e forum annuel trilatéral sur la sardine du Pacifique s'est récemment tenu à Vancouver (Colombie-Britannique). Cette rencontre réunissait des scientifiques, des gestionnaires et des acteurs de l'industrie de la pêche du Mexique, des États-Unis et du Canada, et avait pour objet de mutualiser l'information et d'échanger sur les travaux de recherche portant sur la sardine de la côte ouest nord-américaine. Les groupes de discussion se sont penchés sur trois grands thèmes : 1) état actuel des stocks et plans d'évaluation pour la prochaine saison; 2) résultats des campagnes d'identification des stocks et projets de recherche actuels et à venir; 3) enjeux et préoccupations de l'industrie. Les gestionnaires de la ressource ont fait le bilan des débarquements enregistrés lors de la saison dernière et des prévisions établies pour l'année en cours. Les résultats des études effectuées ont été présentés lors de deux séances d'information à caractère scientifique.

2006 Trinational Sardine Forum participants at the Listel Hotel, Vancouver, British Columbia, Canada

INTRODUCTION

The 7th Trinational Sardine Forum (TSF) was held in Vancouver, British Columbia, Canada, on November 1-3, 2006. The meeting took place at the Listel Vancouver and was attended by 40 participants representing the fishing industry, scientists, governments, First Nations and academia from Canada, Mexico, and the United States (Appendix I). This Forum was made possible through generous funding from Fisheries & Oceans Canada (DFO), the Provincial Government of British Columbia (BC) and the Canadian Pacific Sardine Association (CPSA). A special thank you goes out to the TSF Logistics Committee; Don Pepper (CPSA), Jake Schweigert (DFO), Dennis Chalmers (Province of BC), Christa Hrabok (DFO) and Sandra Merk (Insight Productions).

The Forum was inaugurated by Jake Schweigert (DFO) and Bob Emmett (National Oceanic & Atmospheric Administration [NOAA]). Three special guests provided introductory comments; Mr. Bud Graham, Assistant Deputy Minister in the Ministry of Environment for BC, Dr. Laura Richards, Regional Director of Science for DFO, and Mr. Sergio Rios, Senior Trade Commissioner Western Canada & Pacific NW USA from the Foreign Trade Bank of Mexico,. All three guests discussed the importance of the TSFs in facilitating information exchange and positive collaborations between the three nations. They alluded to the fact that this open communication is essential for maintaining sustainable stocks while promoting viable sardine fisheries for all three countries.

Mr. Bud Graham reviewed the fishery since its inception in 1917. He discussed how the fishery grew and supported a major industry along the BC coast until the 1947 collapse. The optimism resulting from the possible development of another major fishery given the return of the sardine to the coast was also discussed. However, he noted that the optimism has not become a reality for the BC sardine fishery which still struggles to become viable. Many changing global pressures, such as global warming, demographics and markets, are factors that are impacting fish stocks all over the world.

Dr. Richards voiced her support for the Tri-national Sardine Forum and the opportunity it provides for scientists to exchange information on this resource. She noted the long history of scientific collaboration among the three countries in studying all aspects of the sardine population and its biology and management.

Mr. Sergio Rios focused much of his presentation on the North American Free Trade Agreement (NAFTA), particularly as it relates to Mexico. He reviewed the Mexican trade industry, discussing the importance of both imports and exports with the main trading partners. He discussed the importance of NAFTA within the three nations, Mexico, USA and Canada, and noted incentives for doing more business with Mexico.

The opening statements were followed by the two sessions: "Regional Sardine Fishery Reports" and "Research Plans and Reports". Most of the scientific papers presented were oriented toward documenting patterns in the regional fisheries and gaining a better understanding of stock structure and size, migratory patterns, and reproductive capacity of Pacific sardine through the use of a variety of techniques. This year there were also two focus sessions. The first centered on a review and discussion of the coast wide survey conducted during 2006. The second involved a review and discussion of the role of sardine in the ecosystem identifying this as a possible theme for future collaborative research among the three countries.

The presentations were followed by the working group discussions on the afternoon of the second day and summaries provided at the plenary session on the third morning. The Forum drew to a close at noon following an agreement to reconvene in 2007.

The executive committee of the Trinational Sardine Forum represents all three countries: Nancy Lo (United States), Sharon Herzka (Mexico), Robert Emmett (United States), and Jake Schweigert (Canada). The committee members take turns organizing and hosting the meeting. Next year's Forum will be held in San Diego, United States co-chaired by Nancy Lo and Sharon Herzka.

PLENARY SESSION HIGHLIGHTS

Regional Sardine Fisheries Reports

Mexico

Gulf of California

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CRIP– Guaymas, INP
(*Full summary in Appendix III.)

The small pelagic fish of the Gulf of California sustain the most important fishery in Mexico. The catch is comprised of several species of sardines, anchovies and mackerel, although the Pacific sardine (*Sardinops caeruleus*) historically has been the target species. The catches are presented for the fishing season 2005-2006. A total catch of 355,150 t was landed, of which 35.6% was Pacific sardine, 29.7% was "Bocona" (an Anchovy, *Cetengraulis mysticetus*), 16.4% was "Crinuda" sardine (*Opisthonema spp.*), 11.8% was Northern anchovy (*Engraulis mordax*), 3.7% was mackerel (*Scomber japonicus*), 2.0% was round herring (*Etrumeus teres*), and the

remaining 0.7% was "Piña" sardine (*Oligoplites spp.*). In the months of December of the 2005 to June of the 2006 the catches fluctuated between 31,790 t and 49,600 t per month, mostly due to the greater availability of Pacific sardine and an abundance of "Bocona" and Northern anchovy in areas close to Guaymas and Yavaros. The sea surface temperature was relatively cold, with negative anomalies in the months of October to March, although the pattern of winds was "normal"; in the same period the winds blew with northerly component, which promotes upwelling along the Sonora coast. These environmental features could explain (at least partly) the behavior of the catches during 2005-2006 and the significant increment of the landings relative to the last two fishing seasons.

Bahia Magdalena

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From January 2003 to August 2006 a total of 2,845 fishing trips occurred in Bahia Magdalena, B.C.S. and 171,718 t of sardine (all the species) was caught, 83% was of Pacific sardine *Sardinops sagax*. The rest of the catch was represented by the sardine thread herring *Opisthonema* sp (12%), the anchoveta *Cetengraulis mysticetus* (2%), the round herring *Etrumeus teres* (2%) and the Pacific mackerel *Scomber japonicus* (0.4%). The Pacific sardine was fished all year, except in January 2004. A change was observed in the seasonal pattern of the landings, the months with the largest catch of Pacific sardine were April to October during 2003 (> 4,000 t month^{-1}), July to November during 2004 (> 3,000 t month^{-1}), and from March to July during 2005 (> 4,000 t month^{-1}). The thread herring, was practically absent during the second half of 2004 and represented 20% of the annual catch. This species was practically absent in 2005 (0.6% of the year catch), increasing the round herring catch (12%). Eighty-five percent of the Pacific sardine size structure, in Bahia Magdalena during 2004, was smaller than 150 mm SL. During July to December, 100% of the Pacific sardine was smaller than 150 mm. The group of age-1 sardine was predominant from February to May. In June, we observed the widest length and age range of the year. There were two defined length modes, one smaller than 150 mm and the other bigger than 150 mm, with the age-2 group dominant. During the second half of the year the sizes were smaller than 150 mm SL, dominated by the fish of the age-0 group. That pattern in size and age structure continued until April 2005, and from then until September the percentage of sardines smaller than 150 mm decreased to 17%, similar to the 2003 pattern. Nevertheless the reduction in average size of the Pacific sardine during the last two years, no decrease was detected in the total catch. The predominance of small (group-0) fish in the catch is related with a reproductive success during 2004.

Ensenada

Alfredo Cota-Villavicencio, Ricardo Troncoso-Gaytan and Celia Eva Cotero-Altamirano, CRIP – Ensenada, INP

This work presents the *status quo* of the small pelagic fishery for the year 2006; using the daily samples especially sardine and the reports obtained from the log books of the fleet in Ensenada, B. C., Mexico. During the period of the first 9 months of the year 2006 43,022.8 metric tons were captured of which 96.3% of the catches were Pacific sardine, 3.1% for Pacific mackerel and 0.49% for anchovy. The most important fishing period takes place during the summer months, with a tendency of the fleet to move from the north near Coronado Islands at the start of the year to the south of Ensenada by end of the summer and beginning of the fall. The size composition of the Pacific sardine, which is the target species of the fishery, shows a monthly mean size above the legal limit of 150 mm of standard length with larger individuals coming from the south. Fifteen vessels registered this year with a capacity of less than 200 metric tonnes. Of this fleet, only 7 vessels actually operated.

United States

California

Leeanne M. Laughlin (CDFG)

During 2005, 38,193 t of Pacific sardine, with an ex-vessel value of more than $3.1 million, was landed in California, representing a 13.1% decrease in commercial sardine landings over 2004 (43,942 t). Most of California's 2005 catch was landed in the Los Angeles (69.9%) and Monterey (23.5%) port areas. The California fishery caught 34% of the total U.S. landings and 28% of the total U.S. harvest guideline of 136,179 t. During 2005, the Harvest Guideline was allocated on a geographic basis between California and the Pacific Northwest U.S. states, but a new, coastwide allocation based on season was decided on and put into effect for the 2006 fishing season. For both 2005 and 2006, California landings were less than the combined landings of Oregon and Washington.

Oregon and Washington

Brett Wiedoff (ODFW) and Michele Culver (WDFW)

In February of 2005 the sardine industry asked ODFW staff to move Pacific sardines off the developmental fisheries species list and place the fishery into its own limited entry system. In December 2005, the Oregon Fish and Wildlife Commission adopted a new limited entry system for the 2006 fishery. Initially, 20 permits were issues by the Department and in August 2006 the Commission added 6 more permits.

In 2006 a total of 26 permits were issued but only 15 permitted vessels are actively participating in the fishery. This year, the first Oregon landings occurred at the end of June. As of the second week of September 15,087 mt have been landed into Oregon. This is roughly half the amount landed at this time in 2005. In past years, the majority (59% - 75%) of the harvest activity occurred off Oregon, with the remainder of the activity occurring off Washington as far north as the mouth of Willapa Bay. In 2006, the main area of catch has been focused just a few miles north and south of the Columbia River mouth. The Oregon sardine fishery stopped on October 28th and the preliminary sardine landing total for 2006 is 36,680 metric tons.

Current market conditions and small fish leave little room for the sale of fish as fish are smaller than the desired market size and based on industry input, fish caught in 2005 remain in buyer's freezers. Added to that, the Japanese fleet started fishing domestically for sardines. This has hindered sales and landings.

The Washington fishery continues to be managed under their "experimental" fishery designation. A total of 19 permits were issued in 2006. Seven of the 19 permitted vessels have participated in the 2006 sardine fishery and 2,770 mt have been landed into Washington as of September 15th. Sardines have been landed into the ports of Westport and Ilwaco exclusively this year with about 60% of the sardines landing into Westport. As with Oregon, market conditions and small fish have hindered the sales of sardines in Washington. More fishermen would like to participate in the 2006 fishery, but it is extremely hard for many of them to find a viable market.

Beginning in 2007, WDFW will require permit holders to have an ownership interest of at least 50% in the vessel being used in the sardine fishery. The intent is to transition the fishery out of an "experimental" status into an established commercial fishery in 2008.

The websites for tracking each state's landings are:
Oregon, www.dfw.state.or.us/mrp/finfish/cps.asp;
Washington, http://wdfw.wa.gov/fish/commercial/sardine/sardine_creel06.htm

Canada

British Columbia

Cory Paterson and Christa Hrabok (DFO)

The sardine fishery has been active since 1996 in BC coastal waters. Since its inception, the fishery has been guided under the New and Emerging Fisheries Policy (NEFP). From 1996 -2002, the fishery operated under Stage one and two of the NEFP. In 2002, the Pacific sardine was delisted from the COSEWIC list as a 'species

of special concern'. The 2002 – 2003 sardine fishery was a transition period of the fishery moving towards Stage three, a commercial fishery. Since 2003, the Pacific sardine fishery has been in a commercial fishery status.

In 2006, the fishery was open from July to February 9, 2007. There were 50 available licences, 25 communal commercial and 25 commercial. The fishery operated under an Individual Vessel Quota (IVQ) management regime where licence stacking or pooling is not permitted. The fishery had a mandatory catch monitoring program that was 50% at-sea observer coverage and 100% dockside monitoring. All licences had a mandatory logbook requirement and were required to hail in and out. Through self funding arrangements with the Canadian Pacific Sardine Association, $118K was collected to cover science and management costs.

In 2006 out of the 50 available licences, 19 vessels participated. A total of 1557.8 metric tonnes of sardines were caught. This amount of catch represents the same amount caught in 2000. Catches were made on the west coast of Vancouver Island, the lower central coast and primarily off the eastern tip of Vancouver Island in the Port Hardy area. Bycatch was minimal being 0.26% of the total catch weight.

There were a number of complex issues surrounding the 2006 Canadian fishery. One major issue was that market demands were not favorable. The market for large fish dried up which left us to compete with the US for the same market. Another major issue was the lack of capacity the processors had for dealing with sardines. Sockeye and hake fisheries plugged the processing capacity, freezer space, trucking and ice availability, in both Port Hardy and in Vancouver. Since the market-sized fish were mainly located in the Port Hardy area, the fleet had to contend with capacity issues.

Research Plans and Reports

Assessment of the Pacific Sardine (*Sardinops sagax caerulea*) Population for US Management in 2007

Kevin T. Hill[1], Nancy C. H. Lo[1], Beverly J. Macewicz[1], and Roberto Felix-Uraga[2]
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A Pacific sardine stock assessment is conducted annually in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline for the U.S. fishery. The assessment has been updated for 2007 management; as such, it will be reviewed by the PFMC's advisory bodies in

October (Portland, OR) and November (San Diego, CA), 2006. Population modeling was conducted using 'ASAP', a forward simulation, likelihood-based, age-structured model developed in AD Model Builder. New data has been incorporated into the update, including: (1) Ensenada landings through December 2005; (2) an additional year of landings and biological data from the California and Pacific Northwest fisheries; and (3) DEPM-based estimates of SSB from the April 2006 survey.

Preliminary results from the base assessment model indicate a general leveling or decline in stock productivity (recruits per spawning biomass) which began in the mid-1990s. Recruit (age-0) abundance increased rapidly from low levels in 1982 to about 9.8 billion fish in 1994. Recruitment has subsequently declined, with the exception of a strong 2003 year class (YC). Recruit abundance is poorly estimated for recent years, however, the 2003 YC had approximately 14.3 billion fish. The 2003 YC has represented a large portion of the catch, as well as having relatively high abundance in fishery-independent trawl surveys off California and the Pacific Northwest. Spawning stock biomass (SSB) was estimated to be approximately 1.16 mmt in 2006; well within range of DEPM estimates of 1.08 mmt (San Diego to San Francisco) and 1.3 mmt (San Diego to Vancouver) from the 2006 survey. Age 1+ biomass peaked at 1.56 million metric tons (mmt) in 1996-97, declining to 0.97 mmt in 2003-04. Age 1+ biomass has subsequently increased to about 1.3 mmt as of July 2006.

Preliminary Results of US Northwest Surveys in 2003-2005

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We reported the preliminary estimates of biomass and migration rates of Pacific sardine off Oregon and Washing based on a series of northwest survey for Pacific sardine conducted in July 2003- July 2005 with two surveys each year: in March and July. The July 2005 cruise was cancelled due to lack of funding. In each survey, trawl, Calvet, CUFES and acoustic samples and environmental data were taken. The biomass based on swept trawl method was 325,537 mt (cv=0.4) for July 2003, 330614 mt (cv=0.8) for March 2004, 83,066mt (cv=0.3) for July 2004 and 43,864 mt (cv=0.7) for March 2005. The biomasses in July surveys were higher than those of March surveys, primarily due to migration. The rough estimates of the overall migration rates of Pacific sardine from northwest to California water in the fall season is from 0.5 to 0.9 and the migration rate from California water to the northwest in the summer is close to 0.2. The age-specific migration rates from NW to California were obtained but not for migration from California to NW. Other purposes of the series of surveys were to obtain the age or size composition and biological characteristics of Pacific sardine, e.g. the reproductive parameters.

Focus Session – Coastwide Survey

Review of the coast wide survey in 2006 and plans for 2007

Roger Hewitt, Southwest Fisheries Science Center, presented a brief overview of the coast-wide (Vancouver Island to San Diego) sardine survey conducted in April 2006. Two NOAA ships were involved: the *Oscar Dyson*, working from north to south, and the *David Starr Jordan*, working from south to north. Sampling operations on each ship included continuous egg sampling (CUFES), multi-frequency acoustics, CalVET and bongo plankton tows, CTD profiles, and marine mammal and seabird observations. In addition, the *Dyson* conducted direct sampling of juvenile and adult fish using an epi-pelagic trawl.

The original survey design called for the *David Starr Jordan* to also conduct trawl sampling, but mechanical problems precluded this operation. As a result the spacing between the *Dyson* sampling lines was increased and the survey area covered was extended further south (see Figure 1).

Preliminary estimate of spawning biomass of sardines from the egg production method was 1.3 million tons (17% estimated north of San Francisco) with CV of 47%. Preliminary estimate of total biomass of epi-pelagic fish (sardines, anchovy, mackerel) from an analysis of acoustic data was 2.1 million tons (5% estimated north of San Francisco) with a CV of 79%.

Discussion ensued regarding similar surveys in the future and how they might be conducted given limited availability of survey vessels. A west coast survey of hake is scheduled for the summer of 2007 aboard the NOAA Ship *Miller Freeman*, and there was consensus among attendees that the possibility of a joint hake-sardine survey should be pursued. Subsequent to the meeting, discussions between west coast NMFS Science Centers resulted in an additional 6-days of *Miller Freeman* time allocated to a sardine survey separate from the hake survey. Consequently, two sardine surveys are planned for 2007: one in April between San Diego and San Francisco and a more limited survey in June to be staged out of Newport. On a more optimistic note, current ship time allocations on the *David Starr Jordan* and *Miller Freeman* will allow us to plan for another coastwise sardine survey in April 2008.

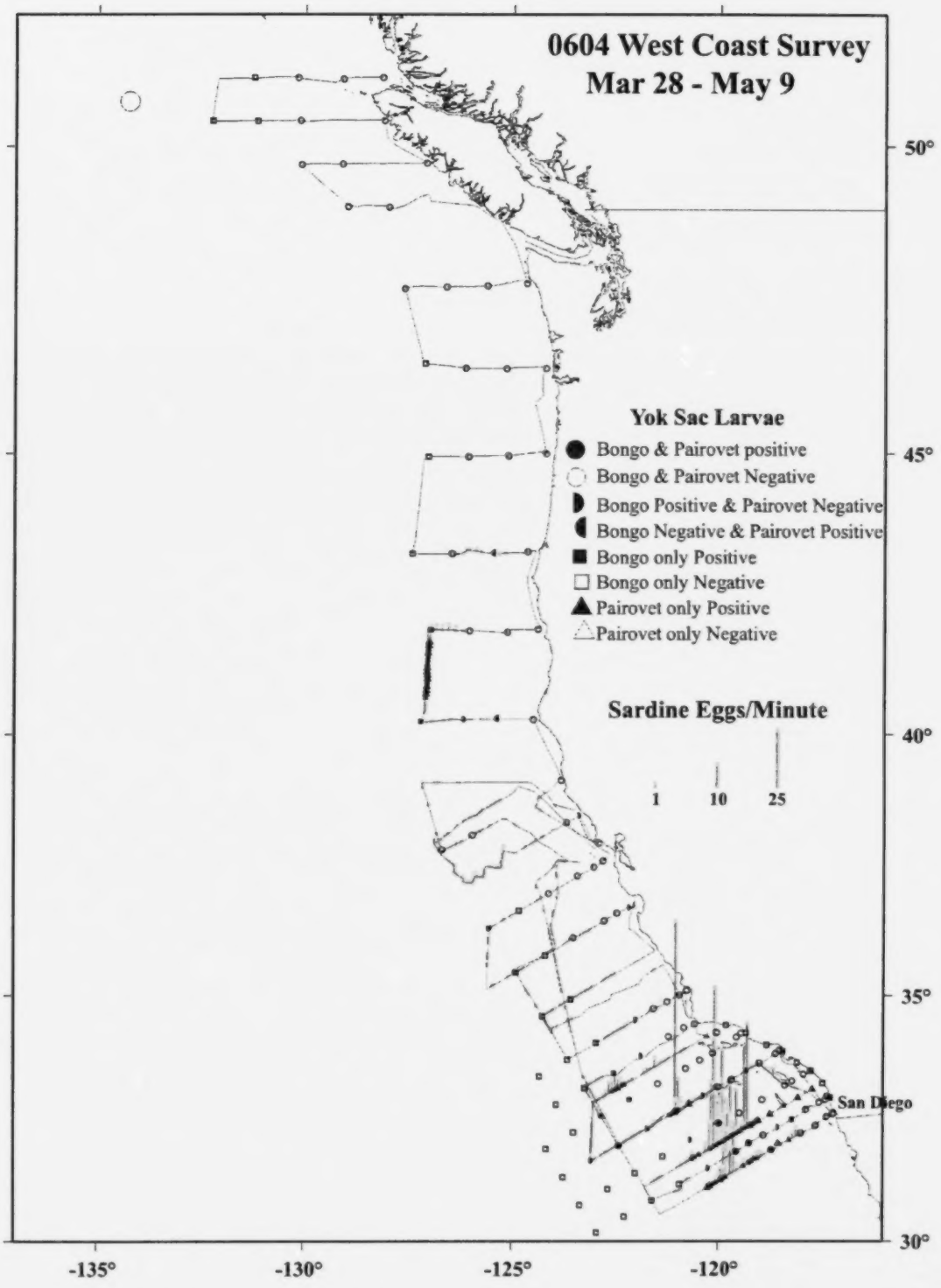

Figure 1. Sampling grid for the 2006 coastwide sardine survey.

WORKING GROUP REPORTS

Working Group 1 – Regional Estimates of Biomass of 2006 and Recommendations

Partial list of members: Martin E. Hernandez-Rivas, mrivas@vedipn.ipn.mx; Sandy McFarlane, mcfarlanes@dfo-mpo.gc.ca, Jake Schweigert, SchweigertJ@pac.dfo-mpo.gc.ca; Robert Emmett, robert.emmett@noaa.gov; Green-Ruiz, motagreen@yahoo.com.mx;Darrell Kapp, dkapp@netos.com; Richard Charter, Richard.Charter@noaa.gov, Nancy C.H. Lo, Nancy.Lo@noaa.gov, Beverly Macewicz, Bev.Macewicz@noaa.gov, Rick Brodeur , Rick.Brodeur@noaa.gov, Roger Hewitt Roger.Hewitt@noaa.gov, Manuel Nevariz, nevarezm@gys.megared.net.mx, and Enrique Morales, embojorq@ipn.mx, Kevin Hill, Kevin.Hill@noaa.gov

1. Coast-wide survey, CalCOFI, and IMECOCAL April cruises, 2006

Objectives: To estimate spawning biomass of Pacific sardine from Baja California, Mexico to Vancouver Island, British Columbia, Canada.

A coast-wide sardine survey recommended in 2005 and at previous Trinational Sardine Forums (Hunter and Plescher-Steele 2003, Lo et al. 2006) was conducted in April-May, 2006 from 24^0-50^0 N. All three countries participated in this survey: two US NOAA research vessels and two Mexican research vessels were used. Scientists from US and Canada participated in surveys aboard NOAA vessels to cover the waters off the west coast of North America from San Diego, US to northern Vancouver Island B.C. Canada (CalCOFI line 95 or 31^0 N - 51°N). Mexican scientists conducted surveys off Mexican water from CalCOFI lines 97-130 (24^0-31^0 N).

Activities:

Coast-wide sardine survey and CalCOFI, April cruise, 2006.

R/V Oscar Dyson was scheduled to occupy the area between 50^0-38^0 N and David Starr Jordan to occupy the area from CalCOFI line 95-57 in April-May 2006. Due to the malfunction of trawling aboard Jordan, the cruise track patterns were revised for both Dyson and Jordan (see below). In addition, the regular CalCOFI April cruise was conducted aboard New Horizon to cover the area from CalCOFI lines 93,3-76,6 (Fig. 2).

Dyson occupied 17 lines from lat 50^0 -31^0N. Except for the first two lines with distance of 60 nm apart, the distance between lines was 80 nm apart for all other lines. Cufes and trawl samples were taken during the entire cruise while CalVET and Bongo samples were taken in the area north of lat 40 aboard Dyson. The *New*

Horizon, the regular CalCOFI cruise (April 1-17 for 2006) occupied the six regular CalCOFI lines (93.3 - 76.6) taking CalVET and Bongo tows and the *Jordan* cruise (April 1-30 for 2006) occupied 10 CalCOFI lines (95- 51.7) with mostly 60 nm apart except the first two lines 95.5 and 91.7). A total of 27 distinguished lines were occupied by three vessels (Fig. 2, 3). Bongo samples were taken only at regular CalCOFI survey stations aboard both the R/V *New Horizon* in the south and the R/V *David Starr Jordan* on CalCOFI line 95.5 and four lines from 71.7 - 57. For both Dyson and Jordan cruises, CalVET tows were taken at 4 nm intervals on each line after the egg density from each of two consecutive CUFES samples exceeded 1 egg/min and CalVET tows were stopped after the egg density from each of two consecutive CUFES samples was less than 1 egg/min. The threshold of 1 egg/min was reduced from the number used in years prior to 2002 (2 eggs/min) to increase the area identified as the high density area and, subsequently, to increase the number of CalVET samples. This adaptive allocation sampling was similar to the 1997 survey (Lo et al. 2001).

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000 (Fig. 2, 3). Beginning in 2001 (Lo 2001), the CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population with the survey area post-stratified into high density and low density areas according to the egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high density area have been used to model embryonic mortality curve in the high density area and later converted to the daily egg production, P_0, for the whole survey area.

For adult samples, the trawl survey was conducted only on the NOAA vessel *Oscar Dyson* from April 12 to May 7 during the 2006 west coast sardine survey; the NOAA vessel *David Starr Jordan* was not used to collect adult samples due to malfunction of the trawl equipment. Trawling was conducted at night near the surface (0-6 fathoms) or in the daytime at depths of 40-140 meters at predetermined regularly spaced stations which is different than the adaptive trawling conducted in 2004 and 2005 where the presence of sardine eggs in CUFES collections identified potential trawl sites. Off the west coast, out of 40 trawls taken; none of the daytime trawls contained Pacific sardines and 10 night time trawls were positive for sardines (Fig. 2, 3).

Estimates of the spawning biomass of Pacific sardine (*Sardinops sagax*) were obtained for the entire survey area and the area traditionally occupied by the Daily Egg Production Method (DEPM) survey between CalCOFI lines 60-93, respectively using the DEPM (Lo et al. 1996, Macewicz et al. 1996). The spawning biomass for the entire survey area was estimated to be 1,304,806 mt (CV = 0.47) for an area of 885,523 km^2. The daily egg production estimate was 0.75/0.05m^2 (CV = 0.23) although no eggs were collected in the area north of latitude 44°N; the daily specific fecundity was calculated as 10.18 (number of eggs/population weight (g)/day) using

the estimates of reproductive parameters from 132 mature female Pacific sardine: *F*, mean batch fecundity, 20882 eggs/batch (CV = 0.114); *S*, fraction spawning per day, 0.083 females spawning per day (CV = 0.37); W_f, mean female fish weight, 76.72 g (CV = 0.089); and *R*, sex ratio of females by weight, 0.449 (CV = 0.047). The standard sampling area in 2006 off California, from San Diego to San Francisco (CalCOFI line 93-60), was 336,774 km^2. For this area, using the egg production estimate of 1.37/0.05m^2 (CV = 0.26) and the daily specific fecundity of 8.47 (number of eggs/population weight (g)/day), the spawning biomass was estimated to be 1,081,612 mt (CV=0.47). The estimates of the mature female Pacific sardine reproductive parameters in the standard sampling area from 7 positive trawls and 86 mature females were: *F*, mean batch fecundity, 18152 eggs/batch (CV = 0.106); *S*, fraction spawning per day, 0.0698 females spawning per day (CV = 0.33); W_f, mean female fish weight, 67.41 g (CV = 0.0658); and *R*, sex ratio of females by weight, 0.451 (CV = 0.073). .The estimates of spawning biomass of Pacific sardine in 1994 - 2006 are 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, and 485,000 mt, 300,000 mt, 600,000 mt and 1.08 million mt respectively. Finally, the spawning biomass north of CalCOFI line 60 from San Francisco, US to Vancouver Island, Canada was calculated, by difference, to be 223,194 mt.

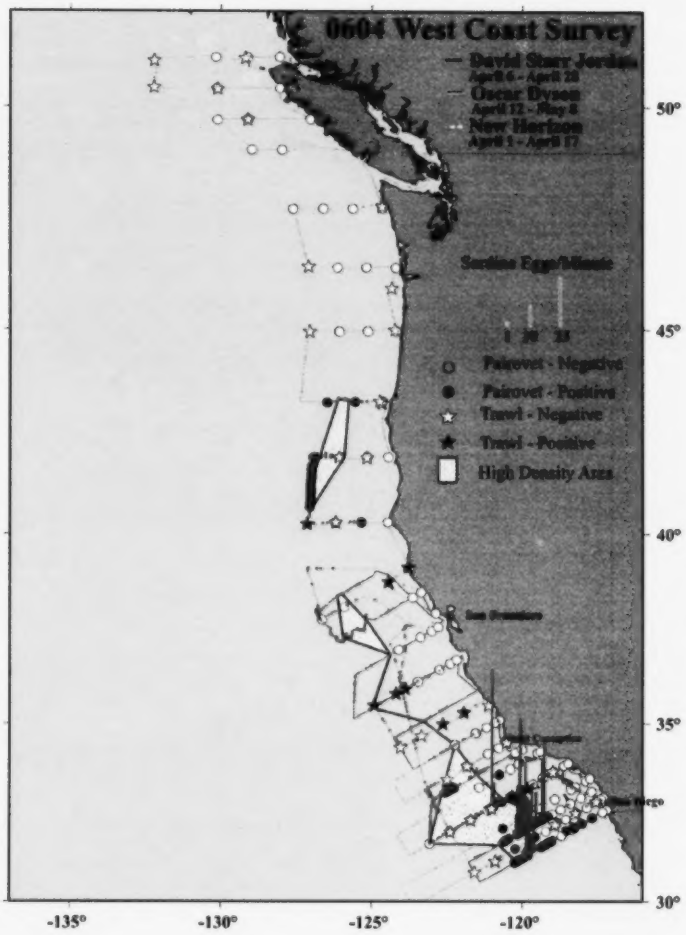

Figure 2. Sardine eggs from CalVET (or Pairovet; circles) and from CUFES (stick denotes positive collection) and trawl samples (stars) in April-May 2006 survey. The solid symbols are positive collections and the open symbols are zero catches.

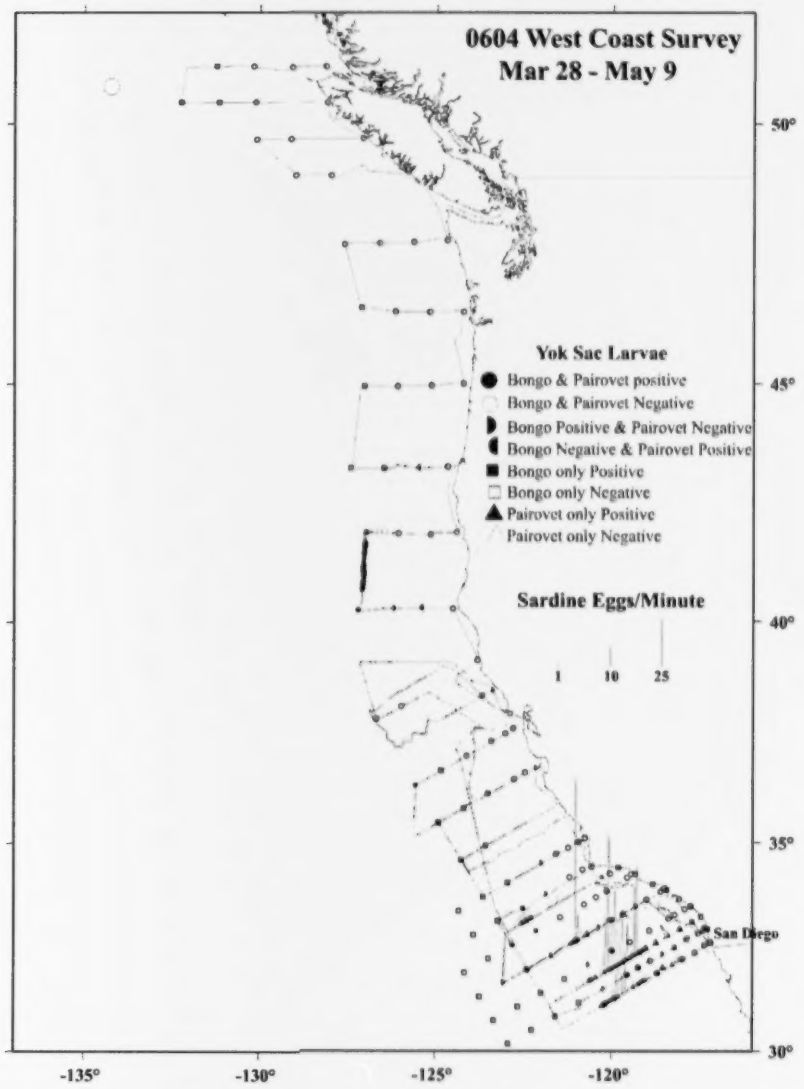

Figure 3. Sardine yolk-sac larvae from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) in April-May 2006 survey. Solid symbols are positive and open symbols are zero catch.

1.2 Coast wide survey and IMECOCAL in 2006

Spawning biomass was estimated for years: 1997-1999, 2002 and 2003 as 2662, 59,000, 94,000, 48,000 and 9,200mt. The first three estimates were computed from sardine larval data and the 2002 and 2003 spawning biomasses were estimated from CUFES egg samples from IMELCOCAL surveys (Lo et al. 2006). The CUFES data from 0404 survey were counted and the distribution of eggs of sardine was plotted together with surveys off California (Fig. 4).

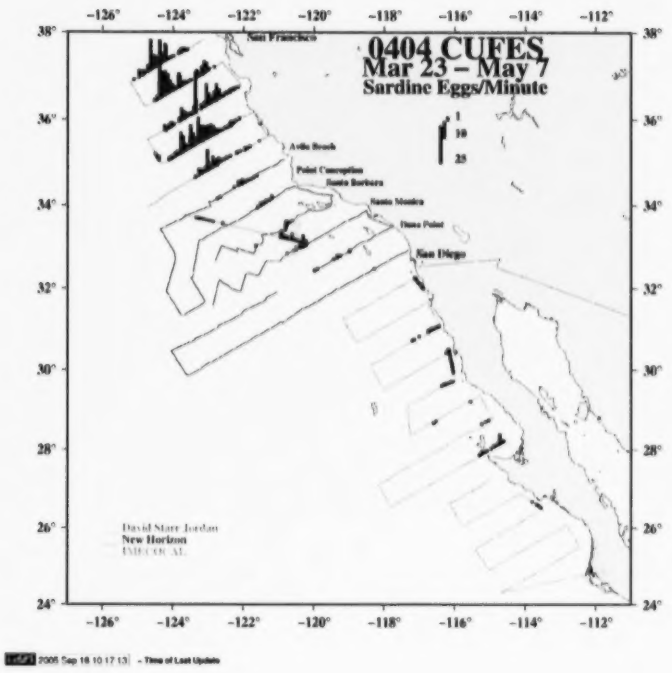

Figure 4. Sardine egg densities from CUFES based on CalCOFI, and IMECOCAL divided by the boarder line in April, 2004...

As the collaboration effort for the coast wide survey, icthyoplankton survey of Mexico was conducted by scientists of Instituto Nacional de la Pesca (INP) aboard R/V/ El PUMA, April 3-24, 2006 and the trawl survey was conducted aboard R/V BIP XI, April 4-24, 2006 from CalCOFI Line 97-130, Ensenada to Punta Abreojos (Fig. 5 and 6). A total of 383 Pairovet and 80 Bongo tows were planned. Due to bad weather, 322 Pairovet and 69 Bongo tows up to 120 nm offshore were collected. A total of 85% of the survey area was covered. Thirty stations were not covered and the survey did not reach to 180 nm offshore as planned. All samples are currently being processed at the CRIP-MAZATLAN. For the trawl survey, the plan was to take trawl samples where the density of eggs from the CUFES was high up to 50 nm offshore. The distance between transect lines was 20 nm.

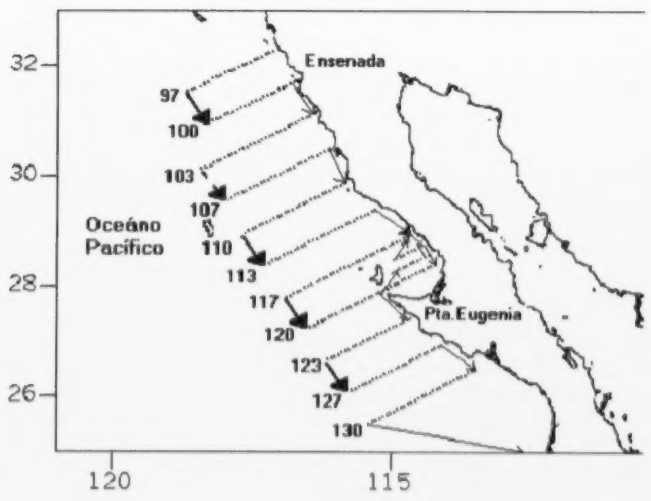

Figure 5. Survey area of coast-wide ichthyoplankton survey off Mexico, April 3-24, 2006.

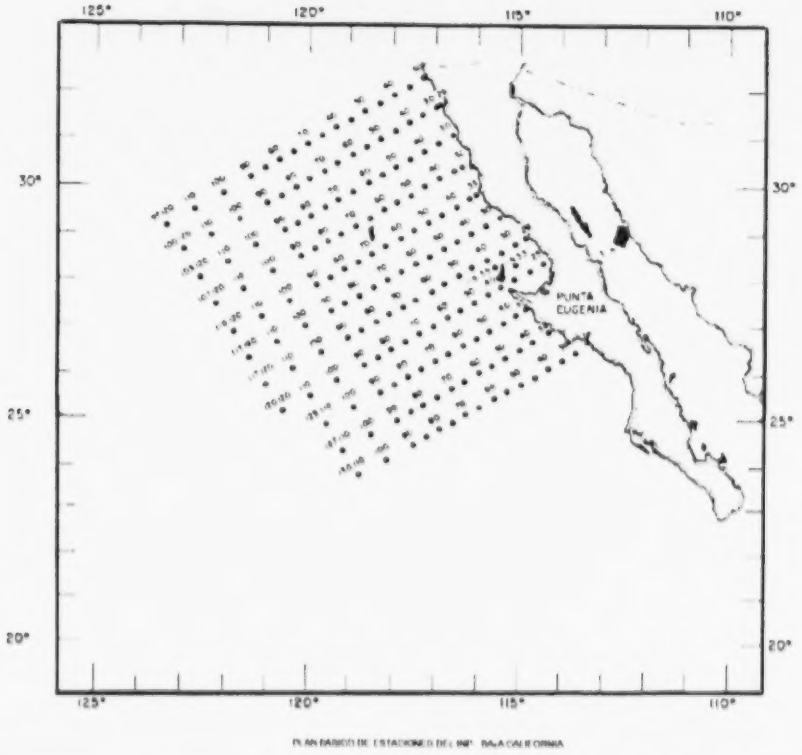

Figure 6. Survey area of the Coast-wide trawl survey off Mexico aboard BIP XI from April 4-24, 2006.

2. Pacific Sardine Biomass Estimates and Associated Information off Northern Oregon and Southern Washington.

Objectives: To estimate spawning biomass of Pacific sardine off Oregon since 1994.

Activities:

2.1 Egg surveys were conducted in 1994-1998

2.2. Adult surveys:

Since 2001, no off shore survey has been conducted to capture adults in June because locations and timing of the spawning were unknown. Effort was concentrated on near shore trawling surveys off Oregon and Washington:

a) BPA (Bonneville Power Administration) Columbia River plume study: daytime surface trawl from northern Washington to Newport in May, June, and September.
b) Predator/baitfish study off the Columbia River: night surface trawl surveys off the Columbia River every 10 days from late April through early August.
c) Lower Columbia River purse seine survey: every 2 weeks from April through September.

In past years a monthly purse seine study in the Columbia River estuary documented use of the estuary by sub yearling and yearling sardines (item c). Vessel problems caused this project to be canceled in 2004. This project has not been carried out since 2005, therefore only two surface trawl surveys (items a and b) collected Pacific sardines off Oregon/Washington in 2006:

This section reports the preliminary estimates of biomass of Pacific sardine based on July samples from night surface survey trawls of predator/baitfish study off the Columbia River from Willapa Bay down to Tillamook Head in 1999-present (Fig. 7). Night surface trawls were conducted every 10 days from late April through early August. During each survey, 12 surface trawls were conducted: 6 on 2 lines (Willapa Bay and the Columbia) from 6 distances from shore: 0-10, 10-20, 50-60 km which constitute six strata. The net reached down to 20 meters depth of water:

Two lines (Willapa and Columbia River) were surveyed every 10 days from late April through July since 1999.

Gear – 264 rope trawl – mouth opening of 360 m^2

2.3 Population estimates off Columbia River region.

Sardine population estimates in the Columbia River region were calculated using the same methodology of past years (volume swept methodology). Sardines captured during the Predator/Forage Fish Survey are usually most abundant in July and August. As such, only July and August information was used to estimate population estimates. The late July/August estimate used information from just August because weather caused us to abort the late July cruise. During each cruise (2 days, 12 trawls) the mean number/m^3 was calculated using the number captured divided by the volume swept. Total density in the study area (Fig. 7) was calculated by multiplying mean sardine/m^3 by 1.52×10^{11} [area of the study area (7,600 km^2) x 20 m]. Average weight of sardines captured was calculated from mean length.

The sardine biomass estimates for 2006 ranged from 378 MT of sardines in mid-July to 11,285 MT in August (Table 1). The August estimates are similar to the early July 2005 estimates (11,399 MT). However, wide fluctuations in population estimates can be expected because sardines have very patchy distributions, and they show large movements both within and outside the study area.

The length/frequency data (Fig. 8) indicate that sardines in the Columbia River area were composed primarily of one size class. Overall, average sardine lengths in July and August were slightly smaller than previous years (Table 1). Oregon/Washington coastal surveys (Fig. 9) showed two size classes in June and three in September (Fig. 10). Compared to the last few years, few 0-age sardines were captured in September 2006 (Fig. 10), indicating that recruitment from 2006 Northwest spawning was not as successful as in 2004 and 2005, when many 0-age sardine were caught (Fig. 11). This may have been related to the intense upwelling and colder ocean temperatures that occurred off the Northwest in 2006.

The ocean was relatively cold in 2006 compared to past years (Fig. 12). Past reports have shown that warm ocean conditions in May/June appear to be conducive for successful spawning and recruitment of Pacific sardine off the Oregon/Washington coast. While June surface temperatures in 2006 were relatively warm, average sea surface temperatures in July and August were below average (Fig. 12).

These data indicate that sardines had low recruitment from spawning off the Northwest in 2006. As such, the sardine population in the California Current will only have limited additional sardine biomass originating from Northwest spawning in 2006.

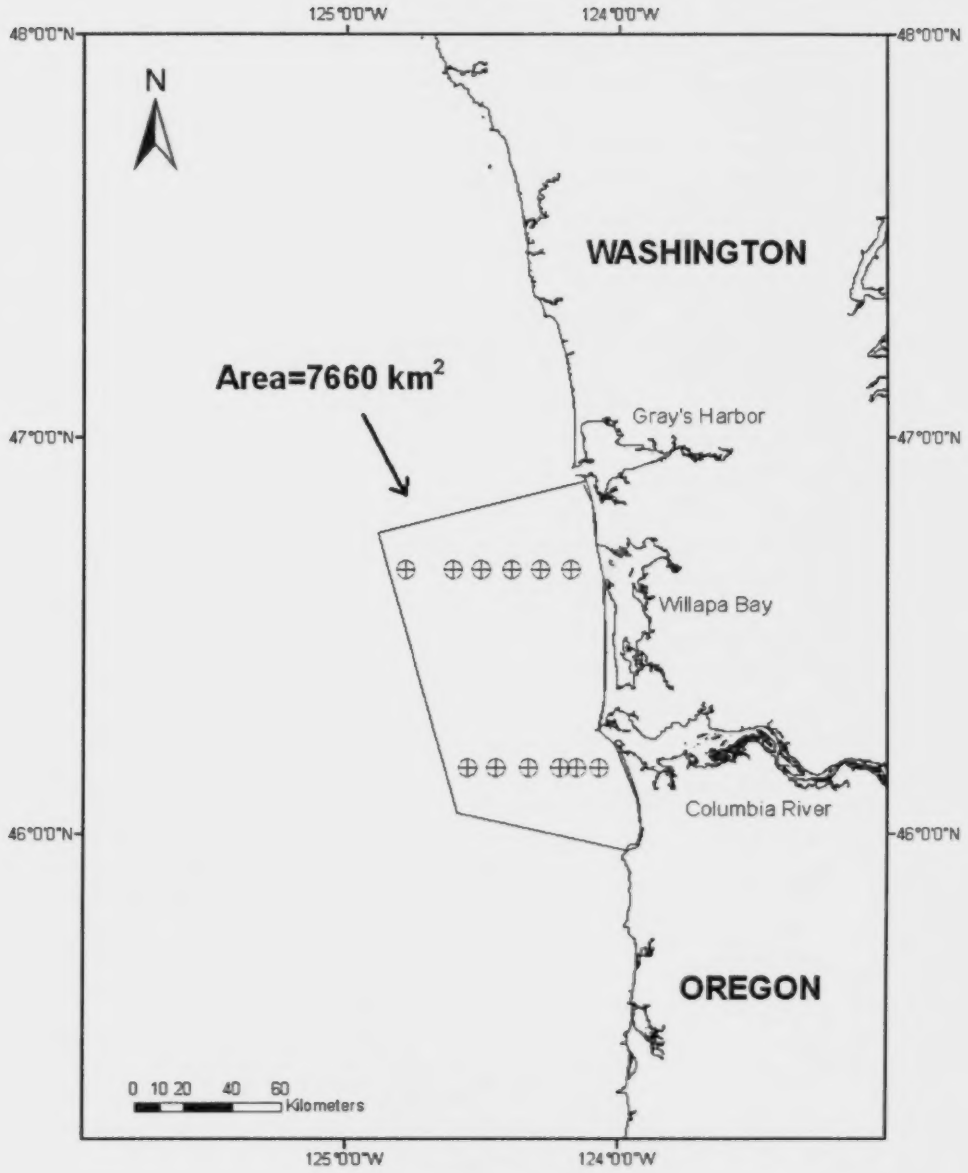

Figure 7. Location of the 12 surface trawl locations sampled at night approximately every 10 days near the Columbia River from late April through early August. Estimated representative survey area – 7,660 km^2 (From above Grays Harbor to Cape Falcon – and out ~35 nm). Total volume (4 x 10^{11} m^3) within the survey area was calculated using 20 m (depth the net fished) x the survey area.

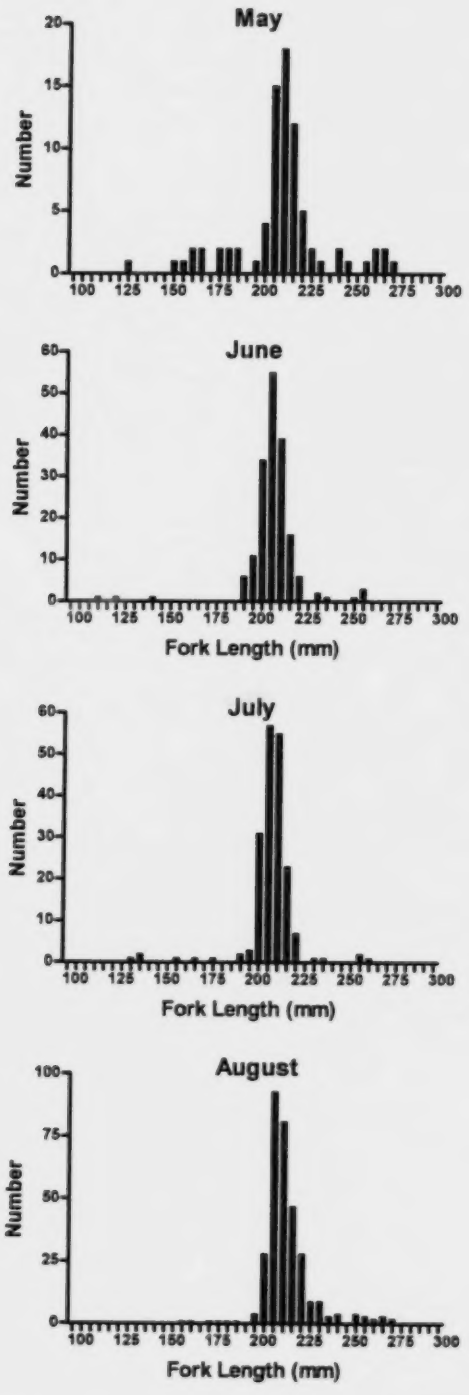

Figure 8. Length frequency of Pacific sardine(Sardinops sagax) captured off the Columbia River in 2006 during the predator/forage fish study.

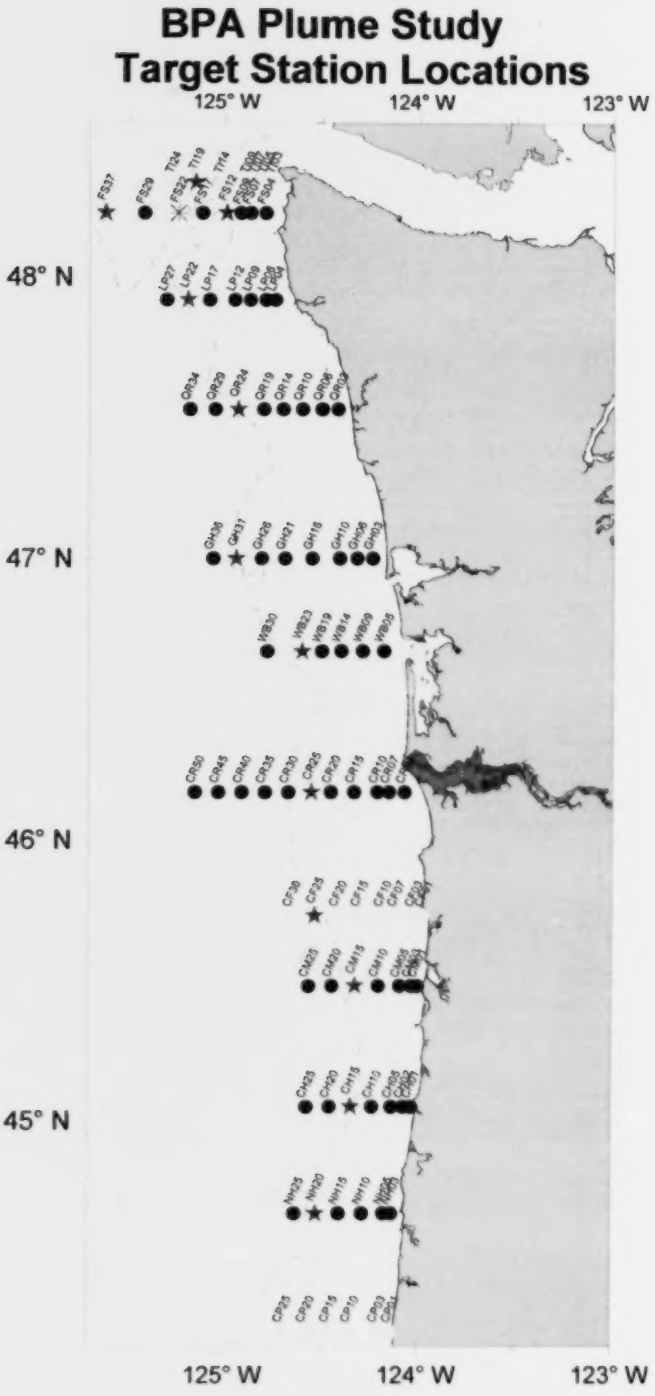

Figure 9. Location of stations sampled annually in June and September off Oregon/Washington during the BPA plume study.

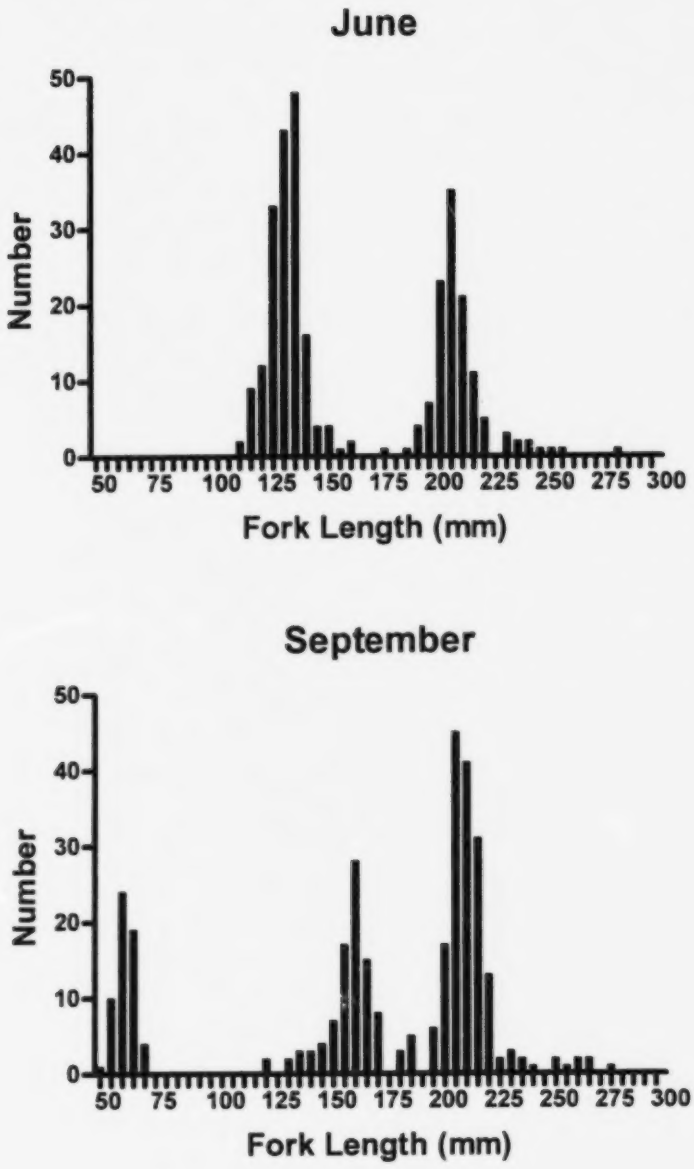

Figure 10. Length frequency of Pacific sardine (*Sardinops sagax*) captured off Oregon/Washington in 2006 during BPA plume study.

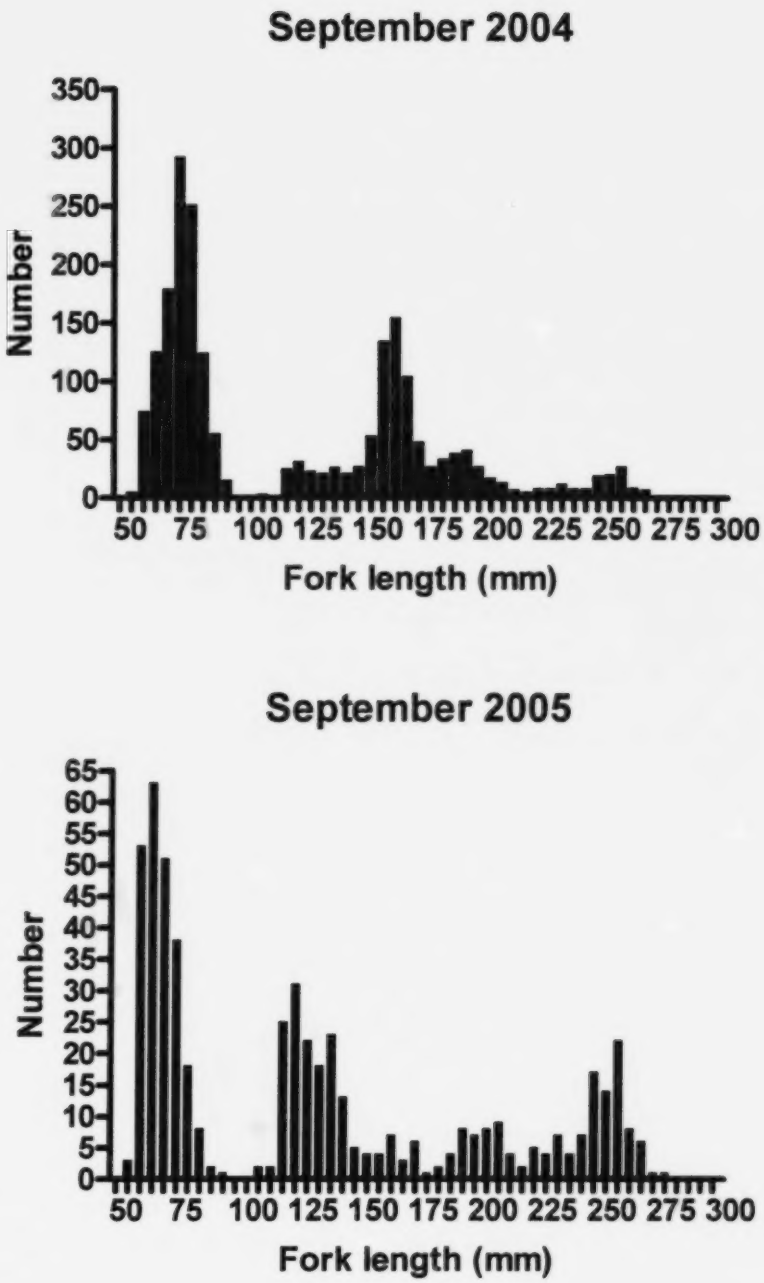

Figure 11. Length frequency of Pacific sardine captured during September 2004 and 2005 off the Oregon/Washington coast during BPA plume study.

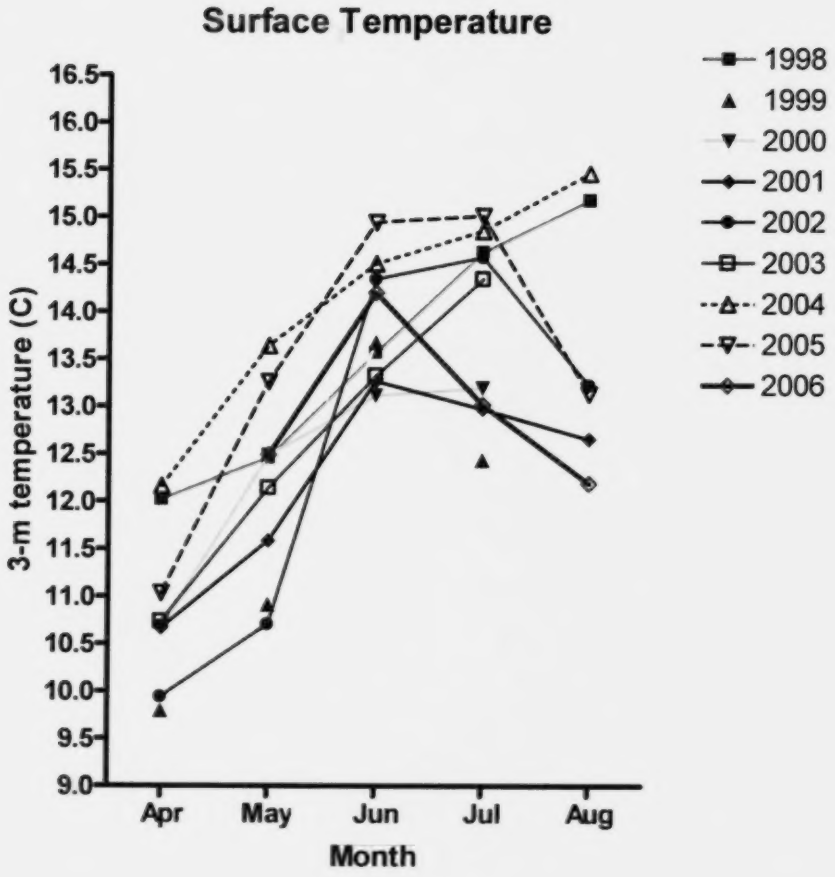

Figure 12. Average monthly surface temperatures (3 m depth) off the Columbia River.

Table 1. Statistics on Pacific sardine (*Sardinops sagax*) captured off the Columbia River region since 1999.

Estimated Number of Pacific Sardine off S Wash/N Oregon

Year	early July	Mid July	Late July/early August
1999	6,361,531	4,298,041	110,264,191
2000	246,539,570	293,661,085	no trawls after 22 July 2000
2001	13,547,385	61,691,990	89,693,132
2002	207,891,576	18,538,962	non taken
2003	10,259,428	847,269,268	73,626,122
2004	11,672,862	79,086,033	173,551,785
2005	156,052,620	No Trawls	103,173,678
2006	5,948,632	3,829,993	106,931,506

Average Length of Pacific Sardine

Year	early July	Mid July	Late July/early August
1999	246	239	235
2000	237	243	
2001	233	241	242
2002	247	247	
2003	251	249	237
2004	108 and 256	135 and 251	143 and 245
2005	189	No Trawls	190
2006	207	210	215

Average weight of Pacific Sardine (g) Calculated from average length

Year	early July	Mid July	Late July
1999	154	143	137
2000	140	149	
2001	133	146	148
2002	156	156	
2003	165	160	140
2004	22 and 248	41 and 236	48 and 220
2005	73	No Trawls	74
2006	95	99	106

Biomass of Pacific Sardine off S Wash/N Oregon (metric tons)

Year	Early July	Mid July	Late July/early August
1999	985	613	14,984
2000	34,475	43,845	No Trawls
2001	1,802	8,980	13,289
2002	32,529	2,892	No Trawls
2003	1,690	211,098	10,290
2004	2,705	5,533	36,574
2005	11,399	No Trawls	7,621
2006	564	378	11,285

3. Canadian Trawl Surveys of Pacific Sardine Abundance in B.C. Waters during 2006.

Objectives: To provide information on the distribution and presence and absence of sardine, biological parameters, and feeding behaviour and to estimate a minimum biomass of Pacific sardine off Vancouver Island from the July survey each year since 1996

Background:

From 1992 to 1996 small numbers of sardines were captured in both commercial and research sets targeting Pacific hake off the southwest coast of Vancouver Island. Since 1997, large numbers of sardines have been captured in surface water research sets targeted on sardine off the west and northeast coasts of Vancouver Island, Queen Charlotte Sound, and in a small commercial fishery for sardines in inlets surrounding Vancouver Island. From 1997 to 1999, sardines were found in the Strait of Juan de Fuca, in the Strait of Georgia, along the west coast of Vancouver Island, Hecate Strait, and off southeast Alaska. Sardine distribution in 2000 was concentrated on the WCVI and ranged as far south as Barkley Sound and as far north as mainland British Columbia, north of Vancouver Island. From 2001 to 2003, sardine distribution became progressively concentrated near shore along the southwest Vancouver Island coast and progressively less prevalent in research cruises. By 2004, sardines were rarely captured offshore or along the research grid; however, large catches of sardines were made in inlets and the shallows along the WCVI, and in 2004 in Queen Charlotte Sound inlets.

Activities:

This report summarizes sardine data collected during a research cruise conducted from July 31 to August 8, 2006. Research cruises have obtained sardine samples since 1992. This is the 6 th survey directed at estimating abundance in offshore waters along the WCVI.

The 2006 research cruise was carried out aboard the R/V W.E. Ricker, and all fish were captured using a model 250/350/14 mid water rope trawl (Cantrawl Pacific Ltd., Richmond, British Columbia). Fish were measured for fork lengths recorded to the nearest millimetre. Biological samples were also collected for sex, maturity, stomachs and otoliths (Table 2).

From July 31 to August 8, 2006, a total of 45 sets were made in surface waters (<45m) off the west coast of Vancouver Island (Fig. 13). Of these, 42 sets contained sardines. All sets were made at night.

During the 2006 cruise, sardines were again captured along the entire west coast of Vancouver Island, including the offshore sites (Fig. 13) suggesting a return to distribution patterns seen in the late 1990s.

Biomass estimates were calculated according to the method described in Beamish et al. (2000). The west coast of Vancouver Island was partitioned into 6 major "regions" and total volume was determined to allow biomass estimates to be calculated regionally. Volume swept during each set was determined by multiplying the area of the mid-water trawl net used during the fishing operations by the distance traveled during fishing. Minimum and maximum estimates were determined using the 95% Confidence Interval for the calculated average swept volume within each major area. In previous years, sardines were captured from sufficient sets along the west coast of Vancouver Island to estimate abundance in all 6 regions to provide an overall estimate for coast wide abundance. Biomass estimates had not been completed for recent years as the numbers of sardines captured and the distribution of offshore catches preclude obtaining meaningful results. This year sardine distribution was again widespread off the WCVI and biomass estimates calculated (Table 3).

Using ratios of sardines in areas 4, 5, 6 and 1, 2, 3 from 1997, 1999 and 2001, biomass estimates were calculated for 2005 (Table 4, Fig. 14). The biomass estimate (upper limit) for 2006 was higher than any previous estimate. This estimate was the first using only night sets. We attempted to adjust the 2006 survey estimate of 258,489 mt to be comparable to previous estimates, which gives us an estimated biomass 18% higher (312,772 mt). We are not confident in the applicability of these adjusted estimates and present them only as a preliminary attempt of understanding the time series.

At this point, just under 1600 mt have been landed with the majority coming from the northeast coast of Vancouver Island. In addition, sardines have again been captured in inlets adjacent to Vancouver Island, Hecate Strait and Queen Charlotte Sound. Since large numbers of fish were captured outside of the survey area, the biomass estimates presented here should be considered minimum estimates.

Table 2. Summary of biological samples taken onboard the W.E. Ricker July 31-August 8, 2006.

2006 Pacific Sardine Sample Summary	
Type of Sample	**# of Sardines**
Weight	**1119**
Length/Sex	**4201**
Maturity	**994**
Stomach	**353**
Otolith	**450**

Table 3. Estimates of Pacific sardine biomass from 1997 to 2006.

Year	Area	Total Volume (km3)	Average Swept Vol (km3)	Swept Volume 95% CI	Average # fish per area	Average mass of fish per area (kg)	Abundance (Mt)		
							Minimum (ave - 95%CI)	Average	Maximum (ave + 95% CI)
1997	1	91.0	0.0039	0.0007	57	9.4	184.6	217.2	263.9
	2	66.6	0.0042	0.0009	3509	801.0	7499.4	9172.3	11838.4
	3	119.7	0.0031	0.0016	645	106.7	2672.8	4069.4	8522.3
	4	83.9	0.0032	0.0012	12696	2154.3	39454.3	54852.7	89964.5
	5	71.8	0.0028	0.0006	1222	201.6	4234.3	5176.5	6658.0
	6	127.7	0.0021	0.0004	1521	239.3	12901.5	15355.1	18961.0
						Total:	66947	88843	136208
1999	2	66.6	0.0019	0.0002	1186	194.5	6146.1	6744.4	7471.8
	3	119.7	0.0020	0.0001	430	70.8	4126.9	4345.2	4587.9
	4	83.9	0.0019	0.0002	559	91.9	3774.0	4159.3	4632.3
	5	71.8	0.0017	0.0006	1307	215.7	6487.3	8689.9	13157.2
	6	127.7	0.0020	0.0005	5262	877.3	44121.8	55459.3	71123.0
						Total:	64656	79398	100972
2001	1	66.6	0.0019	0.0002	0	0	0	0	0
	2	119.7	0.0020	0.0001	0	0	0	0	0
	3	83.9	0.0015	0.00033	0	0	0	0	0
	4	83.9	0.0017	0.0005	4	0.7	12.7	16.2	22.3
	5	71.8	0.0017	0.0002	4	0.6	21.6	24.7	28.7
	6	127.7	0.0017	0.0005	3616	596.8004	33804.2	43823.7	62284.8
						Total:	33839	43845	62336
2005	4	83.85	0.0017	0.00013	1438	216.61	10002.1	10742.7	11601.7
	5	71.76	0.0016	0.00006	2585	340.04	14610.4	15157.6	15747.2
	6	127.65	0.0016	0.00009	5240	900.33	66058.3	69812.5	74019.0
						Total:	90671	95713	101368
2006	2	66.6	0.0019	0.00008	1577.1	228	7864.8	8215.6	8599.1
	3	119.7	0.0018	0.00019	1422.0	176	10595.5	11741.3	13165.0
	4	83.9	0.0015	0.00033	11035.1	1510	69729.9	85476.6	110409.8
	5	71.8	0.0012	0.00018	9192.5	1154	58381.2	66905.2	78343.8
	6	127.7	0.0019	0.00026	4327.6	632	36511.7	41464.3	47971.3
						Total:	183083	213803	258489

Table 4. Pacific sardine biomass maximum estimates: 2005 and 2006 adjusted to provide comparison to 1997 - 2001.

Year	Maximum (t)	Adjusted (t)
1997	136208	136208
1999	100972	100972
2001	62336	62336
2005*	101368	119614
2006**	258489	312772

*adjusted 18% for missing northern areas

**adjusted 21% for night day conversion

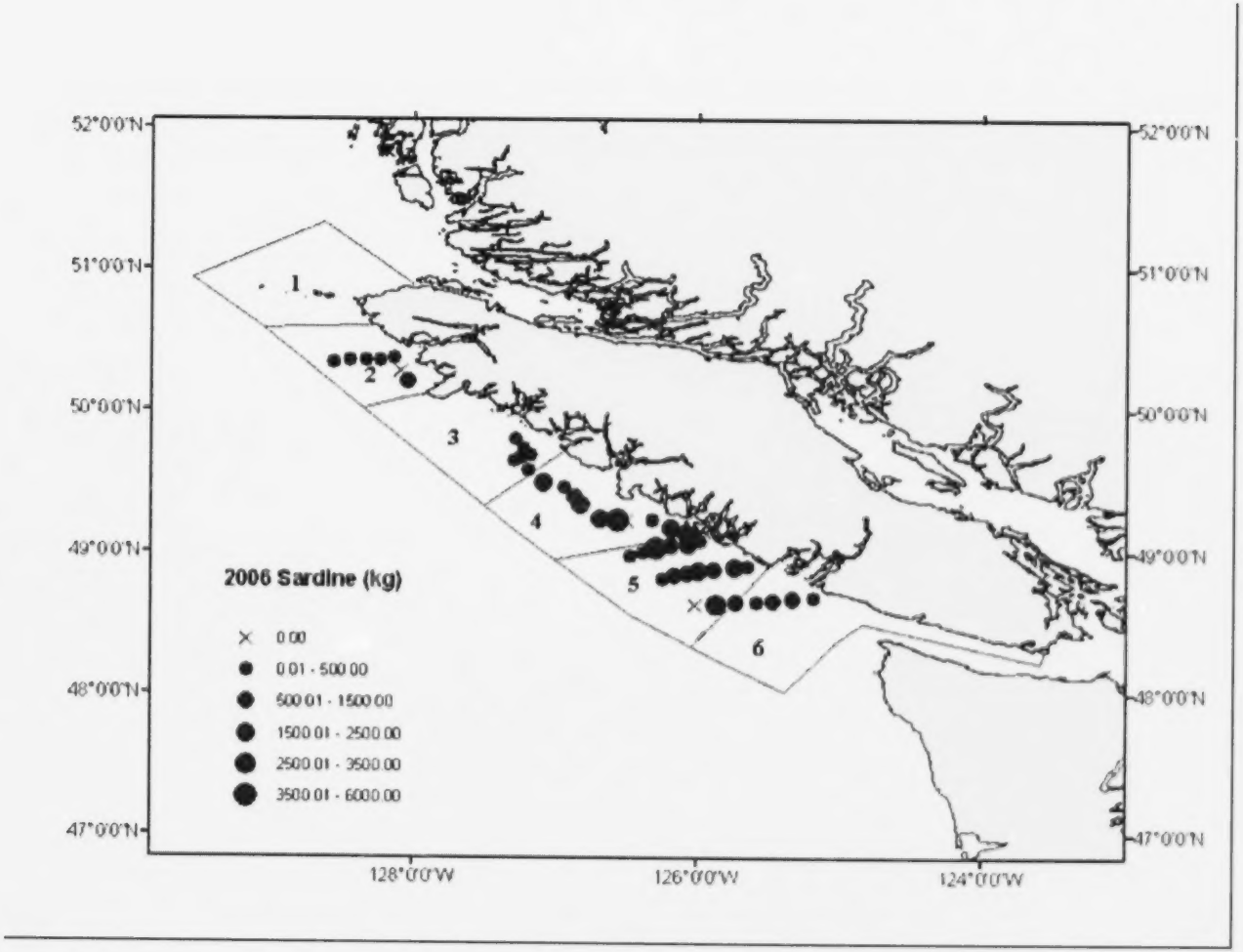

Figure 13. Set locations for the 2006 Pacific sardine cruise off the WCVI, July 31 to August 8, 2006 with region numbers.

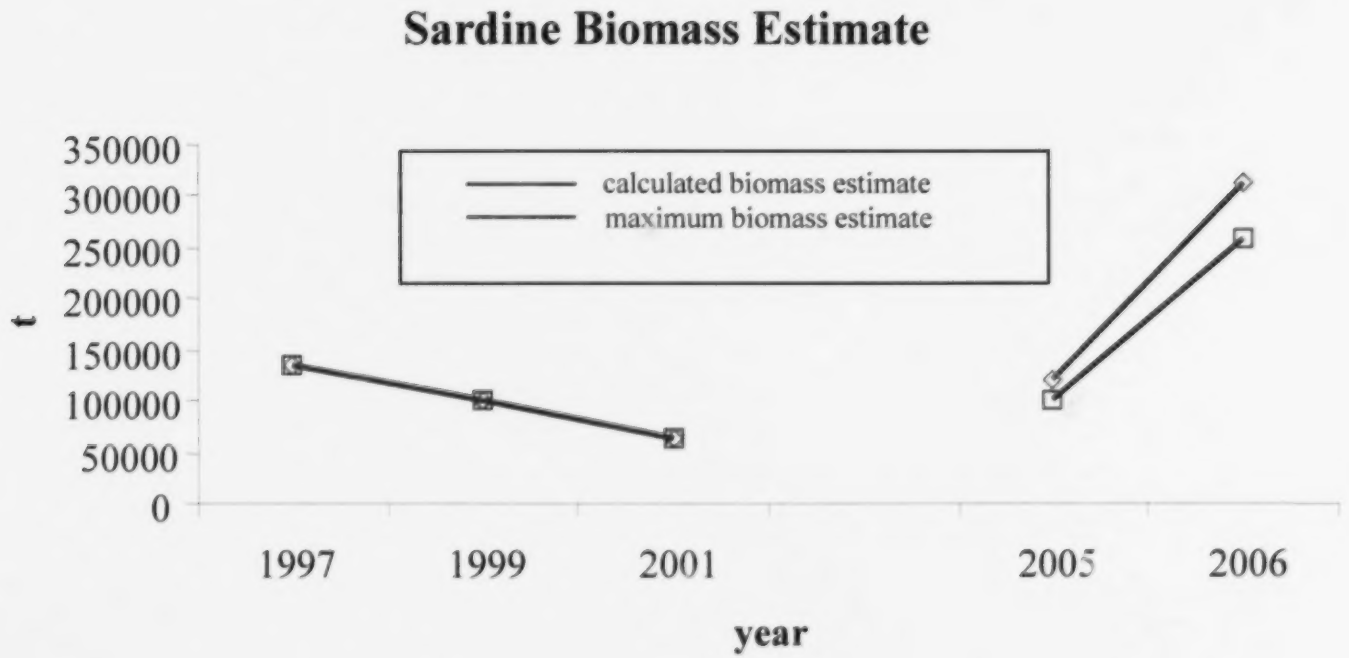

Figure 14. Pacific sardine biomass estimates 1997-2006. Biomass estimate adjusted for 2005 and 2006.

4. IMECOCAL, January survey in South Baja California and Gulf of California.

Objectives: To estimate spawning biomass of Pacific sardine in the southern Baja California, Mexico and in the Gulf of California and to investigate the migration of Pacific sardine between the Gulf and western coast of Baja California.

Acoustic surveys were conducted in the Pacific area outside the Gulf of California in April 2005 and inside the Gulf in April, June and November, 2006, led by Pablo Santos, INP.

5. Future Plans and Recommendations

Canada

Canada will be able to participate in a 2007 July coast wide survey for 7-10 days of ship time as either a part of their regular sardine trawl survey or as part of a hake survey. In the former case, trawls will be taken in the night and trawl samples can be used as biomass estimates. In the day time, bongo tows can be taken. In the case of hake surveys, trawls will be taken in the day time and trawl samples will be used to obtain biological samples only. In either case, CUFES equipment will be loaned to a Canadian research vessel.

The extensively discussed biological, economic and oceanographic model may become a reality in the near future through a new working group proposed during this forum to explore the role of sardine in the eco-system. The working group name proposed was the Sardine-centric ecosystem working group which will possibly be chaired by Sandy Macfarlane.

The industry funded purse seine abundance survey conducted in 2005 was not repeated in 2006 due to the lack of adequate resources.

Mexico

During 2007 two adult sardine surveys will be conducted from the coast to 200 nm offshore, one in Feb-March, and the other in July-Aug,. Also in 2007, the IMECOCAL program will continue with its egg and larval abundance surveys with an unknown number of cruises. However, the INP will conduct an ichthyoplankton survey in January 2008.

It was suggested that sardine biological data from the coast wide survey be compiled to determine the distribution of various characteristics of adult fish, e.g. age distribution, microchemistry traits, etc.

United States.

In 2007, the major undertaking will be to collaborate with the biennial Pacific hake survey to complete a July coast wide survey. In order to do this, some track lines would need to be modified to extend further offshore. This survey will hopefully provide another synoptic estimate of sardine biomass throughout the western coast of the North American continent (as of December, 2006, this collaboration will not be carried out. Instead, a six day ship time was allocated for a sardine survey off the Pacific Northwest in June).

Kevin Hill, SWFSC, requested that a time series of biomass estimates for sardine off Canada, Oregon and Washington be included in the annual stock assessment.

The initial data analyses of four NW surveys from July 2003-March 2005 were conducted. The recommendation from the workshop in the previous TSF to evaluate the survey was deemed unnecessary.

Beverly Macewicz, SWFSC will check into the status of the cps observer program to collect adult samples in March-May in the Southern California Bight to increase the sample size.

Working Group 2 – Stock Structure, Age Structure and Adult Sampling

Participants:

Russ Vetter SWFSC
Jill Smith ODFW
Becka Baldwin OSU/CIMRS
Axa Rocha-Olivares CICESE
Brett Wiedoff ODFW
Bev Macewicz SWFSC
Carina Gutierrez CICESE
Vanessa Hodes DFO
Sharon Herzka CICESE
Christa Hrabok DFO
Ruben Rodriquez-Sanchez CICIMAR

The overall discussion focused on:

1. A detailed discussion and clarification of the results presented during the previous days scientific papers,

2. The status of current studies and planned or contemplated new directions for research and potential new sources of funds.

3. Coordinating, standardizing and simplifying the collection, field processing, preservation and archiving of sardine biological samples for the wide variety of studies currently being carried out or contemplated in the future.

Summary of Discussion

First, progress in otolith chemistry as a measure of natal origin, migration pathways, stock structure, and mixing rates was discussed. Measurements of the stable isotope ratios of oxygen and carbon from otoliths of sardines collected in Mexico the US and Canada show promise. The sampling of animals several months old (which are large enough to be analyzed but small enough to reflect limited spatial and temporal variation in environmental conditions has proven problematic for a number of reasons: these stages are dilute in the water and are not captured in large numbers by typical ichthyoplankton sampling gear. They are never captured by commercial fishing gear. Young of the year, (YOYs) are proving to be valuable sources of otolith material. The assumption is that YOYs are not capable of long distance migrations and thus reflect the regional conditions of temperature and salinity, at least during the first months of life. YOYs from a coherent sample (such as a single net tow) appear to display a wider than anticipated variance in isotopic values. This could be the result of variance in birth date and growth rates (which would lead to variations in carbonate accretion rates) as well as wider than anticipated vertical and horizontal movements of YOYs. Laboratory experiments under controlled conditions can set limits on the between individual variability under constant conditions so that the variance registered in field samples can be apportioned between environmental and individual variability.

Vetter reporting on the results of Dorval, Vetter, Javor and Robertson summarized laboratory rearing experiments that are coming to completion in which sardine have been maintained at three constant temperatures for a year. These experiments are approaching completion. While the core otolith material present when the fish were captured and brought into the laboratory influences isotopic values measured in whole otoliths of fish kept under controlled temperature conditions, the overall trend appears to be consistent with theory Carbonate obtained from milling of the edge material deposited when the fish were only growing in the laboratory will be compared with published values of temperature verses oxygen stable isotopes to improve precision.

Analysis of port sampled YOY from the southern California Bight fishery 1995 to 2002 seems to indicate that YOYs taken from different years reflect the overall range of temperatures experienced in the Bight and that individuals from year classes taken during unusually warm El Nino and cold La Nina years reflect the conditions during the first year of life.

Coastwide sampling of YOYs used for otolith chemistry analyses show a general correlation with a north-south temperature gradient, but some YOYs have an unusual and potentially important anomaly that could be due to the used lowered salinity habitats. This anomaly may be due to fresh water input from the Columbia River. If confirmed, this signal could provide an important method for discriminating between YOYs that recruited and overwintered on the NW coast and potential migrants from the South.

Studies by Valle and Herzka indicate a rough correlation between presumed temperature histories recreated from satellite remote sensing of ocean temperature and otolith stable oxygen isotope values. There is larger than anticipated variance among young individuals collected simultaneously at a variety of locations but in many cases there is also an interesting systematic bias suggesting that the animals spent their previous time somewhere other than where they were captured. There is a general suggestion of movement from inside the Gulf of California to the Magdellena Bay fishery but more samples are needed.

Carina Gutierrez reported the most recent genetic results that were based on a combined study of mitochondrial sequences and nuclear microsatellite markers. To date, results do not show deep genetic differences between the putative stocks. However, they are providing a deeper understanding of the amount and distribution of genetic diversity throughout the present range and allow discussion of the effects of the recent population collapse and subsequent expansion of sardine populations. Within the working group we discussed what types of patterns might be expected from such a dynamic species. New results do not support the Basin model that theorizes that during unfavorable conditions sardine retreated to a single central basin from which they subsequently expanded. The genetic signature of such a process would be a greater amount of genetic variability in the central region with genetic diversity tapering off toward the limits of the distribution (north and south).

Results presented by Rebecca Baldwin on the parasites of sardine provided new insights and a fresh approach to the question of sardine stock structure and movements. Parasites specific to the Vancouver populations appear to hold promise for tracking these stocks.

Ruben Rodriguez-Sanchez presented important new information derived from catch records of the tuna-bait boat fishery for sardine. When combined with long-term temperature records it was clear that sardine availability around the tip of Baja California was not constant and tropical water conditions impinging on the coast could potentially cut the proposed migratory path of sardine isolating populations in the Gulf from populations along the Pacific coast of Baja.

2. Future directions

Among the geneticists, the immediate goals are to expand the numbers of samples and genetic markers that are brought to bear on the problem and initiate a focus on spawning habitats as a more specific test of the presence of separate stocks. Also an expansion of the range of putative population structure to include continuous gradients in genetic diversity as well as sub-stocks seems to be a priority.

Among those interested in otolith chemistry the main short-term goal is to improve the temporal resolution of chemical measurements by subsampling otoliths to get more precise measures of the otolith composition of yearly or seasonal growth increments as well as the natal core.

3. Standardized Sampling Protocol

Improving communication and the organization and standardization of sample collections was a priority among all members of the group regardless of their experimental approach. The most tangible goal is the creation of a written illustrated protocol that will give guidance to field scientists regarding the collection and preservation of tissue samples, the recording of associated biological measurements and the recording of environmental and location information from samples derived from commercial catch sampling and scientific research cruises. Barbara Javor and Beverly Macewicz have agreed to develop a draft protocol that will be circulated among the participants for comment.

The archiving and storage of samples (central location versus many small collections) was also a subject of discussion.

Working Group 3 – Industry Trends and Issues

Don Pepper, CPSA

The Industry Working Group met and considered the inputs the Group could make to the Trilateral Forum (TFS). It was noted that the original impetus for the formation of the TFS was to direct science into the research useful to the industry.

From this it was determined that the Industry Working Group should take a more dynamic approach and provide input to the science. One avenue was to supply input to the proposed ecosystem based group to be chaired by Sandy McFarlane. This raised the question of what inputs could we present? The answer was to supply some simple indicators to allow some degree of predictability on the sardine biomass.

These indicators could come from the following:

- Is the stock growing or contracting? What are the indicators?
- What causes the stock to migrate? Is it temperature or feed or both?
- What causes changes in growth rate(size)?
- What if any are the changes in feed?
- Are there large environmental indicators available? What are they?
- What caused the 2003-year class? Can we predict another?
- How long is the current Baumgartner cycle? 20, 40, 60 years?

To answer these questions the Working Group will have to meet before the next Trinational to provide specific recommendations for the scientists and for new working group.

Recommendation: Don Pepper to coordinate this meeting.

Focus Session – Role of Sardine in the Ecosystem

Sandy McFarlane made a presentation on what is known about the role of sardine in the California Current ecosystem from the physical oceanography and climatology to their effects on the primary and secondary production in this system. It was noted that there was an increasing interest in developing an understanding of how species interact with various components within the ecosystem and that the TSF participants had access to much of the data that would be required to begin to develop models of sardine and how they affect and are affected by other species within the California Current system. A proposal was put forward to hold a series of workshops to gather data, develop ecosystem models for sardine and begin to make forecasts of the effects of climatic change on sardine productivity.

A lively discussion followed the presentation and there was a great deal of interest in following up on this topic. A suggestion was made to establish a working group tentatively titled the Sardine centric ecosystem working group to be chaired by Sandy McFarlane. Further discussion surrounded the issue of funding to pursue this work and the possibility of holding a workshop to bring together interested participants with access to sardine data. A list of potential participants was developed but no tentative dates for the workshop were identified.

CONCLUSIONS

The 7th Annual Trinational Sardine Forum was the first Forum to be held in Canada. The two and a half day event was a big success! A total of 40 delegates attended; 7 from Mexico, 15 from the USA and 18 from Canada. Over the two and a half days, the event covered a number of topics which include; regional fisheries reports, research plans and reports, contributed reports, working group breakouts, a poster session, and two focus sessions. Since its inauguration in 2000, the TSF has proven important to improved understanding of sardine biology and in supporting scientific collaborations. Stock structure remains a particularly difficult issue to resolve as evidenced by the many papers presented at this year's meeting that used a variety of approaches to address this question.

The stock assessment for Pacific sardine was based on a revised version of the model used last year. Indications are that abundance peaked in the mid-1990s following the exponential increase as the population began rebuilding in the early 1980s. Abundance declined slightly through 2004 and increased again due to the recruitment of an exceptionally large 2003 year-class. Coast wide biomass has reached a plateau at just under 1.5 million mt and recruitment has been relatively stable at about 4-6 billion age 0 sardines annually. Landings were similar to 2005 with a slight decrease in the Pacific Northwest.

The long sought after coast-wide survey took place in April and May 2006, covering transect lines between 50° – 24° N and spanning Canada, USA and Mexico. The objective of the survey was to estimate spawning biomass of Pacific sardine from Baja California, Mexico to Vancouver Island, Canada. Two US NOAA research vessels and two Mexican research vessels were used. Scientists from all three countries participated on the cruises. Spawning biomass of the Pacific sardine was estimated in all three countries. No sardine eggs or adults were found north of California, a result that was not unexpected based on historical tagging information.

The new working group on industry trends reiterated the need for closer co-operation between industry and scientists. They suggested a number of areas in which scientists could focus their efforts to support industry. A new working group was also proposed to begin to address questions about sardine interaction with other species in the ecosystem and the role they play as both predators and prey. Although there was widespread support for the working group, there are no funds for new research in the area and it was unclear whether adequate capacity exists within the TSF to make progress on this topic.

The 2007 Forum will be held in San Diego, United States in late November in conjunction with the annual CalCOFI meetings. For more information see (http://swfsc.nmfs.noaa.gov/frd/Trinational/index.htm or http://swfsc.noaa.gov)

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APPENDIX I

LIST OF PARTICIPANTS

Trinational Sardine Forum
Vancouver, Canada
November 1-3, 2006

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APPENDIX II

English Agenda

7th Annual

TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA

2006
AGENDA

The Listel Hotel • Vancouver, BC, Canada

November 1st, 2nd and 3rd, 2006

TUESDAY, OCTOBER 31st

The Listel Hotel, *O'Doul's Restaurant & Bar*

Welcome Gathering

18:00 - 21:00 Welcome Gathering at O'Doul's Restaurant & Bar in the Listel Hotel

WEDNESDAY, NOVEMBER 1ST

The Listel Hotel, *The Impressionist Gallery*

CONFERENCE

08:00 **REGISTRATION**

09:00 Welcome and Opening Remarks, *Jake Schweigert (DFO) and Bob Emmett (NMFS)*

STATEMENTS FROM SPECIAL GUESTS

09:10 Mr. Bud Graham, Assistant Deputy Minister, Ministry of Environment, Province of British Columbia

09:20 Dr. Laura Richards, Regional Director Science, Canada Department Fisheries & Oceans, Pacific Biological Station (DFO - PBS)

09:30 Mr. Sergio Rios, Senior Trade Commissioner Western Canada & Pacific NW USA, Foreign Trade Bank of Mexico/Trade Commission of Mexico

09:40 Meeting Logistics, *Christa Hrabok (DFO)* and *Sandra Merk (Insight Productions)*

REGIONAL SARDINE FISHERIES REPORTS

09:45 Gulf of California, *Manuel Nevárez* (CRIP-Guaymas)

10:05 Bahía Magdalena, *Casimiro Quiñonez-Velazquez, Felipe N. Melo-Barrera,* and *Roberto Felix-Uraga* (CICIMAR)

10:25 Ensenada (N. Baja), *Enrique Morales* (CRIP-Ensenada)

10:45 California, *Kevin Hill* (SWFC)

11:05 Northwest, *Brett Wiedoff* (ODFW) *and Michele Culver* (WDFW)

11:25 Canada , *Cory Paterson and Christa Hrabok* (DFO)

11:45 Discussion

12:00	**LUNCH**
	RESEARCH PLANS AND REPORTS
13:15	Biomass Estimation – General Introduction *Bob Emmett (*NWFSC*)*
13:20	Stock assessment *Kevin Hill (*SWFSC*)*
13:40	Biomass estimates *Nancy Lo (*SWFSC*)*
14:00	Preliminary Results of U.S. Northwest surveys *Nancy Lo, Beverly Macewicz and David Griffith (*SWFSC*)*
14:20	Oregon/Washington *Robert Emmett (*NWFSC*)*
14:40	Canada *Sandy McFarlane and Jake Schweigert (*DFO*)*
15:00	**BREAK**
15:30	Batch fecundity, spawning fraction, and preliminary age of Pacific sardine females caught in research surveys off California, Oregon and Washington. *Beverly J. Macewicz (*SWFSC*)*
15:50	Discussion
	FOCUS SESSION – COASTWIDE SURVEY
16:00	Review of the coast wide survey *Roger Hewitt*
16:15	Discussion
17:00	**ADJOURN**

RECEPTION

18:30 – 20:30	**RECEPTION**
	The Listel Hotel, *The Impressionist Gallery*
	Welcome reception and poster presentations with appetizers, beer and wine.

THURSDAY, NOVEMBER 2nd

The Listel Hotel, *The Impressionist Gallery*

CONFERENCE

08:00 **CONTINENTAL BREAKFAST**

08:30 Stock structure - General introduction
Russ Vetter (SWFSC)

0:835 Genetic Structure of the Northeast Pacific sardine (Sardinops sagax caerulea)
Carina Gutiérrez-Flores (CICESE);*Carol Kimbrell, Eric Lynn* (NOAA), *Casimiro Quiñones-Velazquez* (CICIMAR), *Manuel O. Nevares-Martínez* (CRIP),*Russ J. Vetter* (NOAA), *and Axayacatl Rocha-Olivares* (CICESE).

08:55 Parasites as biological tags for separating northeastern Pacific sardine (Sardinops sagax) stocks.
Kym Jacobson, Robert Emmett (NOAA), *and Rebecca Baldwin* (OSU)

09:15 The stock structure of the Pacific sardine in the California Current System.
Roberto Felix-Uraga (CICIMAR), *Kevin T. Hill* (SWFSC), *Felipe N. Melo-Barrera and Casimiro Quiñonez-Velázquez* (CICIMAR)

09:35 Reconstruction of temperature history and natal origin of the Pacific sardine in Mexican waters based on otolith $\delta^{18}O$.
Sonia R. Valle and Sharon Z. Herzka (CICESE)

09:55 **BREAK**

10:30 Oxygen stable isotopic composition of otoliths may reveal natal origin of Pacific sardines.
Emmanis Dorval, Barbara Javor, Russ Vetter & Larry Robertson (NOAA-SWFSC)

10:50 Pacific sardine (*Sardinops caeruleus*) around the southern tip of the Baja California peninsula, Mexico and its relation to the interannual variability of the California Current. Implications for stock identification and biomass assessment.
Rubén Rodríguez-Sánchez, Sofía Ortega-García and Héctor Villalobos (CICIMAR)

11:10 Ecosystem-based conservation and management of Pacific sardine fisheries: linking the environment, ecology and economics of the California current ecosystem
Samuel F. Herrick, J. G. Norton (NOAA), *and Cindy Bessey* (JIMAR)

11:30 Discussion

11:45 **LUNCH**

13:00 Industry Economics
Don Pepper (CPSA)

14:00	Focus Session – Role of sardine in the ecosystem *Sandy McFarlane & Jake Schweigert (*DFO*)*
14:15	Discussion
15:00	**BREAK**
	WORKING GROUP DISCUSSIONS
15:30	WG 1: Regional biomass - *Nancy Lo* WG 2: Stock structure, age structure and adult sampling – *Russ Vetter* WG 3: Industry trends and issues – *Don Pepper*
17:00	**ADJOURN**

DINNER

18:30	**DINNER**
	Savory Coast Cucina Mediterranea Restaurant (2 blocks from the Listel Vancouver)
	Conference dinner featuring food and wines from British Columbia.

FRIDAY, NOVEMBER 3RD

The Listel Hotel, *The Impressionist Gallery*

CONFERENCE

08:00	**CONTINENTAL BREAKFAST**
	PLENARY SESSIONS FOR REPORTING RESULTS OF WG DISCUSSIONS
08:30	PS 1: Regional Biomass PS 2: Stock Structure PS 3: Industry Trends
10:30	**BREAK**
11:00	Planning for next Meeting & Closing remarks
12:00	**ADJOURN**

POSTER SESSION — November 1st, 2nd and 3rd

The Listel Hotel, *The Impressionist Gallery*

Can otolith trace-element chemistry be used to delineate sardine stocks?
Emmanis Dorval, Barbara Javor, Russ Vetter and *Larry Robertson* (SWFSC)

Posters will be displayed around the meeting hall for the duration of the forum.

WORKING GROUPS / CONTRIBUTORS / COMMITTEES

WORKING GROUPS:

The principal goal of the working groups is to promote coast-wide cooperation in producing information needed regarding the biology and dynamics of the population:

WG1: Regional biomass - Nancy Lo
WG2: Stock structure, age structure and adult sampling - Russ Vetter
WG3: Industry trends and issues – Don Pepper and Orlando Amoroso

CONTRIBUTORS:

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Christa Hrabok, DFO
Dennis Chalmers, Province of BC
Jake Schweigert, DFO
Sandra Merk, Insight Productions

EXECUTIVE COMMITTEE:

Nancy Lo, NOAA
Sharon Herzka, CICESE
Robert Emmett, NOAA
Jake Schweigert, DFO

ACRONYMS

CDFG	California Department of Fish and Game
CICESE	Centro de Investigación y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CPSA	Canadian Pacific Sardine Association
CRIP-INP	Centro Regional de Investigación Pesquera, Instituto Nacional de la Pesca
DFO	Department of Fisheries and Oceans, Canada
JIMAR	Joint Institute of Marine and Atmospheric Research
NWMFS	Northwest Fisheries Science Center, National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
WDFW	Washington Department of Fish and Wildlife

APPENDIX III

CONTRIBUTED ABSTRACTS AND SUMMARIES

(in order of appearance in agenda)

La pesquería de peces pelágicos menores en el Golfo de California, México, temporada de pesca 2005-2006.

The small pelagic fishery in the Gulf of California, México. Fishing season 2005-2006.

Manuel O. Nevárez Martínez[1], Ma. Ángeles Martínez Zavala[1], J. Pablo Santos Molina[1], Myrna L. Anguiano Carrazco[1] y Ángel R. Godínez Cota[1].

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Los peces pelágicos menores del Golfo de California sostienen la pesquería masiva más importante de México. La captura se sustenta en varias especies de sardinas, anchovetas y macarela, aunque la sardina monterrey (*Sardinops caeruleus*) históricamente ha sido la especie objetivo. Aquí se presenta el comportamiento de las capturas durante la temporada de pesca 2005-2006. Durante 2005-2006, se registró una captura total de 348,000 t, de las cuales 36.0% fue de sardina monterrey, 30.2% fue sardina bocona (*Cetengraulis mysticetus*), 15.1% fue sardina crinuda (*Opisthonema spp.*), un 12.1% fue anchoveta (*Engraulis mordax*), un 3.8% fue macarela (*Scomber japonicus*), un 2.1% fue japonesa (*Etrumeus teres*) y el resto lo aporto la sardina piña (*Oligoplites spp.*). En los meses de diciembre del 2005 a junio del 2006 las capturas oscilaron entre 31,700 y 49,600 toneladas por mes, en gran medida a que hubo una mayor disponibilidad de sardina monterrey y una muy alta disponibilidad de sardina bocona y de anchoveta norteña en áreas aledañas a Guaymas y Yavaros. La temperatura superficial del mar fue relativamente fría, presentándose anomalías negativas en los meses de octubre a marzo y por otro lado el patrón de vientos fue normal pues en ese mismo periodo los vientos soplaron con componente norte, los cuales son los que promueven las surgencias a lo largo de las costas de Sonora. Esos rasgos ambientales podrían explicar (al menos en parte) el comportamiento de las capturas durante 2005-06 y el significativo incremento en los desembarcos con respecto a las dos últimas temporadas de pesca.

The small pelagic fish of the Gulf of California sustain the most important massive fishery in Mexico. The catch is sustained for several species of sardines, anchovies and mackerel, although the Pacific sardine (*Sardinops caeruleus*) historically has been the species objective. Here the behavior of the catches is presented for the fishing season 2005-2006. It was registered a total catch of 348,000 t, of which 36.0% was Pacific sardine, 30.2% was "Bocona" (an Anchovy, *Cetengraulis mysticetus*), 15.1% was "Crinuda" sardine (*Opisthonema spp.*), 12.1% was Northern anchovy (*Engraulis*

mordax), 3.8% was mackerel (*Scomber japonicus*), 2.1% was round herring (*Etrumeus teres*), and the remaining 0.7% was "Piña" sardine (*Oligoplites spp.*). In the months of December of the 2005 to June of the 2006 the catches oscillated between 31,700 t and 49,600 t per month, in great measure to that there were a bigger availability of Pacific sardine and a very high availability of "Bocona" and Northern anchovy in near areas to Guaymas and Yavaros. The sea surface temperature was relatively cold, being presented negative anomalies in the months of October to March, and on the other hand the pattern of winds was "normal"; in that same period the winds blew with north component, which are those that promote the upwelling along the Sonora coast. Those environmental features could explain (at least partly) the behavior of the catches during 2005-2006 and the significant increment of the landings with regard to the last two fishing seasons.

GENETIC STRUCTURE OF THE NORTHEAST PACIFIC SARDINE (*Sardinops sagax caerulea*)

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Appropriate management measures require the delineation of stocks or management units. Stocks may be identified as potentially isolated reproductive groups. A genetic approach to stock delineation may allow assessing the contribution from each subpopulation to mixed catches and to the genetic pool of the species. Stock delineation remains controversial for the Pacific sardine (*Sardinops sagax caerulea*), a small pelagic distributed in the the California Current ecosystem.

Studies relating to the population structure have been carried out for over a century. Morphological characters suggest the existence of three allopatric groups/stocks, although Radovish (1982) proposes the existence of a 4th in the northern limit of distribution. Recently, Félix *et al* (2004) proposed the existence of three stocks, identified by distinct temperature affinities, which follow a seasonal pattern of along shore migrations. In spite of these phenotypic differences, previous biochemical and molecular genetic studies have suggested the existence of a single panmictic population from Canada to the Gulf of California.

This research represents the largest genetic effort that has been carried out in this species. Five microsatellite loci and one mitochondrial were used to estimate the genetic diversity and the degree of differentiation of Pacific sardine, including samples from seven localities along the Northeastern Pacific and Gulf of California in Mexico. We have very high values of molecular genetic diversity consistent with a large effective population size. Two hundred and two mitochondrial haplotypes were detected in 218 sequences from adult sardines. Values of haplotypic diversity are larger than 98% and those of nuclear heterozigosity ranged between 82 and 95%. The microsatellite loci of 230 sardines suggest the existence of significantly differentiated geographical groups that partially agree with previous hypothesis of population structure of the Pacific sardine. A more complete picture of the genetic makeup of Pacific sardine populations will be achieved by supplementing our data with those from early life history stages and by analyzing a more comprehensive spatial and temporal array of strategic samples. This work demonstrates the power of some molecular markers to study demographic processes at different scales of space and time.

PARASITES AS BIOLOGICAL TAGS FOR SEPARATING NORTHEASTERN PACIFIC SARDINE (*SARDINOPS SAGAX*) STOCKS

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Parasites have been used to identify stock structure and habitat use of marine fishes worldwide. Approaches have included comparisons between parasite communities and parasite genetics. In 2005 we obtained Pacific sardines from five locations ranging from British Columbia to Southern California as a pilot study to use parasites to help differentiate stocks of Pacific sardines. Sardines were collected from March to July, 2005 from: off Vancouver Island, BC; Willapa Bay, WA; the mouth of the Columbia River; Santa Cruz, CA; and Point Arguello, CA. A total of 272 sardines were examined for macroparasites. The body cavity, stomach, intestine, and gills were examined and all macroparasites recovered were preserved in 70% ethanol. Nine parasite species were recovered. Sardines were moderately infected, with parasite prevalences $\leq$ 53%. Multivariate community analysis of parasite abundance showed spatial separation of the sardines. The five sardine sampling locations could be segregated into three general regions: 1) British Columbia, 2) Washington and Oregon and 3) California (Figure 1). Two different trematodes species were strong predictors of sardine location; *Lecithaster* sp. for Vancouver Island sardines and *Parahemiurus* sp. for California sardines (Figure 1). We were able to address temporal stability of the parasite communities through multiple samples taken off Vancouver Island and Willapa Bay, WA (Figure 2). We also observed differences in the parasite communities of different size-classes of sardines (e.g. the nematode *Anisakis* sp. was more prevalent in sardines >250 mm fork length). The sardines caught off the mouth of the Columbia River in June were significantly larger than the sardines collected from the other locations. Additional samples of large sardines from multiple locations are needed to determine if parasite communities can be used to discriminate large sardines by geographic affinity.

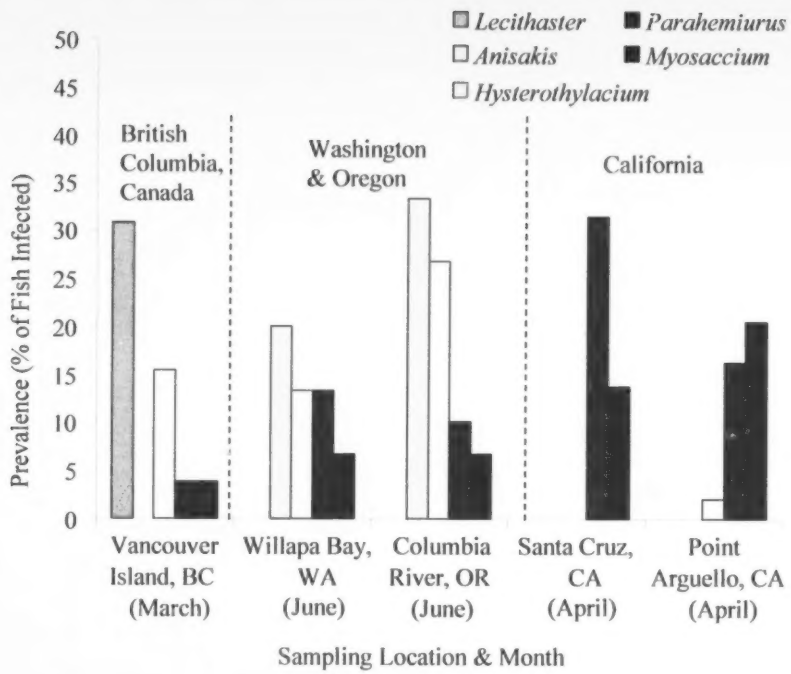

Figure 1. Prevalences of five common parasites infecting Pacific sardine (*Sardinops sagax*) from five areas off the west coast of North America in 2005.

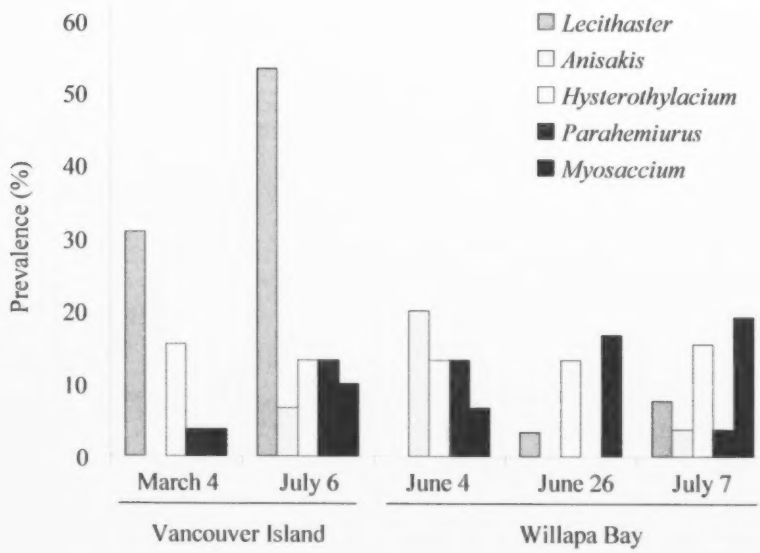

Figure 2. The temporal stability of macroparasite communities found in Pacific sardine (*Sardinops sagax*) collected at two locations in 2005.

THE STOCK STRUCTURE OF THE PACIFIC SARDINE IN THE CALIFORNIA CURRENT SYSTEM.

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Abstract

Three stocks of Pacific sardine were identified in the California Current System using monthly data of landings and sea surface temperature from Magdalena Bay, Cedros Island and Ensenada in Mexico, San Pedro, Monterey, Oregon & Washington in USA, and Vancouver in Canada. One of the stocks seems to be adapted to temperatures higher than 22 °C (warm stock), another to temperatures between 17 °C-22 °C (temperate stock), and the third to temperatures between 13 °C-17 °C (cold stock). The warm stock is only present at south of the Peninsula of Baja California during fall and to the beginning of winter, and probably it comes from the Gulf of California. The tempered stock is present mainly off the west coast of the Peninsula, although in autumn it is off the south of California and in spring in Magdalena Bay. The cold stock is off southern California and north of Baja in winter/spring, and off the Pacific nothwest in summer/fall. The temperate stock seems to have been the largest stock until 2000. During the last five years the cold stock seems to have grown to a bigger size that the temperate stock. Both stocks (the temperate & the cold stocks) are catched in Ensenada and San Pedro, although in Ensenada the proportion of the temperate stock is bigger than that of the cold stock, and in San Pedro this proportion is inverse.

Summary

In this work the stock structure of the Pacific sardine is analysed. Our work hypotesis is that currently several sardine stocks exist in the eastern boundary of the California Current System (CCS). And to prove it, we are using information easy to collect: The monthly landings in seven fishing zones from Magdalena Bay in Mexico to Vancouver in Canada. And the monthly mean of the sea surface temperature (SST). These data are the monthly average of SST in squares of 1° latitude by 1° longitude located in front of each fishing zones.

For Magdalena Bay, landings were classified by sight in two groups. A group seems to be adapted to temperatures between 22° C-27° C (warm stock), and another between 17° C- 22° C (temperate stock). The temperate stock is catched mainly in the first half of the year and the warm one in the second half. In Cedros Island the total catch comes practically from the temperate stock however it is catched in the first half of the year as well as in the second half. In Ensenada it is also possible to find two sardine groups. The temperate stock (catched between 17°C- 22° C) and another group that is catched

to temperatures below 17°C. In San Pedro happens a similar situation to Ensenada, where it is possible to find the same two groups, the temperate and the cold stocks. In Monterey, the whole landings comes from the cold stock. The same situation happens in Oregon and Washington and also in Vancouver. All the sardine landings at Monterey, Oregon, Washington and Vancouver, practically only happens in summer and autumn. When analyzing the sardine landings for all the fishing zones, in the period of 1981 at 2005, we show by sight that exist three groups of Pacific sardine in the eastern boundary of the CCS which seem to be adapted to three different ranges of SST.

Each fishing zone shows a marked seasonality through the year. Most of the sardines in the system of the current of California are catched in the second half of the year.

Temperatures below 13° C are only presented mainly in Oregon, Washington and Vancouver from December to June of every year. In Monterey temperatures equals or smaller than 13°C are presented in the first half of the year.

The monthly catch of sardine landed in each one of the fishing areas of the CCS from 1981 to 2005, shows three periods of abundance. At the beginning of the sardine recovery, low catches period (1981-1989), sardine was only catched in Bay Magdalena and Cedros Island and at the end of this period low catches were also obtained in Ensenada and San Pedro. During 1990 to 1997, catches were increased and also there were more northern catches in Monterey. In the last period (1998-2005) the captures were increased even more and there were also captures more northern as in Oregon, Washington and Vancouver. The colonization of the most northern areas happened gradually (The scale of the catches axis is different in the three graphs).

The graph of the period of high catches (1998-2005) of the previous slide, was used to point out the stock to which belong the monthly catches in each fishing area. The warm stock (in red) is only catched in Magdalena Bay. The temperate stock (in green) is captured in Bay Magdalena, Ensenada, and San Pedro (The fishery in Cedros Island finished in 1966). The cold stock (in blue) is captured from Ensenada to Vancouver. With this, it is possible to detect the latitudinal & seasonal migratory movements of the temperate stock as well as of the cold stock, and the occurrence of the warm stock in Magdalena Bay.

This is a schematic representation of the distribution space-time of the sardine stocks in the eastern boundary of the California Current System. In the winter (January to March), the three stocks move to the south more or less simultaneously, toward areas where they spawn. In spring (April to June), the three stocks reach their more southern distribution where they continue spawning (The warm stock probably enters to the Gulf of California). In summer (July-September), the three stocks move toward the north to more productive areas. In autumn (October-December), the three stocks reach their more northern distribution where the productivity is higher.

The sardine landings in the easter boundary of the CCS has been increasing gradually, from 1984 when 3,700 mt was landed, until the last years when it has been obtained

near 200,000 mt. In the abundance recovery of the Pacific sardine three periods of capture are distinguished. These periods of increment are strongly related with the phenomenon of "El Niño". After of "El Niño" 1983-84 the total catch was increased from 20,000 mt in 1985 to 55,000 mt in 1991. After of "El Niño" 1992-93 the landings were increased of 57,000 mt in 1993 to 129,000 mt in 1997. And finally, after of "El Niño" 1997-98 the catches were increased from 167,000 mt in 2000 to 196,000 mt in 2002 and 186,000 mt in 2005.

"A LA SARDINA LE GUSTA EL NIÑO"

RECONSTRUCTION OF TEMPERATURE HISTORY AND NATAL ORIGIN OF THE PACIFIC SARDINE IN MEXICAN WATERS BASED ON OTOLITH $\delta^{18}O$

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We measured oxygen isotopes in the sagittae of Pacific sardines ($\delta^{18}O_{oto}$) to reconstruct temperature histories and evaluate the suitability of $\delta^{18}O_{oto}$ as natural tracers of natal origin, migration patterns and geographical population structure. Twelve groups of sardines (120-160 mm standard length, up to 1.5 yr old) were collected in the Pacific off Baja California and Gulf of California between May 2004 and May 2005. The temperature to which each individual was exposed during its life was estimated using (1) satellite-derived sea surface temperatures (SST) averaged over the life of each fish and (2) a literature-derived empirical equation based on $\delta^{18}O_{oto}$ values (T_{oto}). There was a negative correlation between $\delta^{18}O_{oto}$ values and SST estimates for Pacific and Gulf samples ($r = -0.49$ and $r = -0.44$, respectively). No significant differences were found in $\delta^{18}O_{oto}$ among samples from the Pacific and Gulf, although there were significant differences among locations within each region. There was a high level of variability in the $\delta^{18}O_{oto}$ values of sardines captured in any one location, indicating diverse temperatures of formation and suggesting mixing within the first year of life. Mean T_{oto} values agreed with SST estimates for most Pacific samples, except for the southernmost Pacific site (Bahía Magdalena), which may reflect movement to the bay system from the Gulf of California and Isla de Cedros region. For Gulf samples, T_{oto} estimates were generally lower than SST estimates, suggesting the preferential use of lower temperature habitats. The $\delta^{18}O_{oto}$ values of sardines could potentially be used to characterize natal origin and migration patterns of the Pacific sardine in the Mexican Pacific.

OXYGEN STABLE ISOTOPIC COMPOSITION OF OTOLITHS MAY REVEAL NATAL ORIGIN OF PACIFIC SARDINES.

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The life history of the Pacific sardine, *Sardinops sagax*, is highly influenced by environmental factors such as temperature. Pacific sardines undergo large-scale migrations between Mexico and the Pacific Northwest (PNW). The effects of temperature on the life stages of Pacific sardines are likely to be recorded in the oxygen isotopic composition [$\delta^{18}O$] of otoliths. In a laboratory experiment we validated the use of [$\delta^{18}O$] to track sardine stocks by varying temperature and food. As expected, otolith [$\delta^{18}O$] negatively correlated with temperature, and was not significantly affected by food or growth rate. We also collected juveniles from four spawning areas: Gulf of California (Mexico), Baja California (Mexico), Southern California Bight (SCB), and PNW. Compared to fish from the PNW, fish from the SCB and Mexico showed distinct isotopic compositions. Contrary to expectation, fish from the PNW showed, on average, the lowest ratios of [$\delta^{18}O$], suggesting that these juveniles may have originated from warm offshore spawning areas. Our preliminary data showed that the dynamics of juvenile sardines may be more complex than previously thought, and otolith [$\delta^{18}O$] may be a useful tracer for distinguishing natal origin of sardine populations.

PACIFIC SARDINE (*Sardinops caeruleus*) AROUND THE SOUTHERN TIP OF THE BAJA CALIFORNIA PENINSULA, MEXICO AND ITS RELATION TO THE INTERANNUAL VARIABILITY OF THE CALIFORNIA CURRENT IMPLICATIONS FOR STOCK IDENTIFICATION AND BIOMASS ASSESSMENT.

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Abstract

Within the total distribution of *Sardinops caeruleus* (from south of Alaska to inside the Gulf of California), with the exception of a recent genetic study, the labeling of a population or isolated stock inside the Gulf of California (GulCa) using different diagnostic characteristics has been mostly justified because of the stock's supposed geographic isolation caused by the Baja California peninsula and the presence of an oceanographic front off the southern end of the Gulf. We have made a revision of the frequency of the annual occurrence of Pacific sardine around the tip of the peninsula using catch records of live bait during the last warming regimen (1980 -1997), a period when it has been suggested a northward geographical shift in the position of the center of distribution and bulk of the biomass of Pacific sardine in the California Current system, which shift could, hypothetically, increase the isolation of a putative sardine population inside the GulCa. We assumed the presence of the species around the tip is related to movements toward either side of the peninsula. These events are discussed in relation to the interannual variability of the sea surface temperature and the advection of the California Current during the same period. We found that sardine abundance in that area increased during years with cold conditions and the increase of a southward advection of the California Current. These conditions seemingly facilitate the movement of fish between the ocean and gulf sides of the peninsula. Additionally, because migrations in all temporal scales of variability potentially have effects on the distribution, recruitment and biomass assessments of exploited fish populations, the results of this work with an annual resolution are discussed together with movements of longer and larger scales previously reported with regard to stock identification and biomass assessment.

Introduction

Numerous authors have regarded the Pacific sardine (*Sardinops caeruleus*) at the Gulf of California as a population or stock distinct from those along the west coast, which ranges from southern Alaska to Bahia Magdalena. Some authors have supported this idea based on several diagnostic characteristics (growth rate, time of birth and recruitment, blood type, and number of vertebrae), though most authors believe the distinct populations are caused solely by the apparent isolation of the gulf by the peninsula and the existence of an oceanic front at its tip, which is assumed to prevent the passage of sardine schools.

We have made a study of the frequency of the annual occurrence of Pacific sardine around the tip of the peninsula using catch records of live bait during the last

warming regime (1980 -1997), a period during which a northward geographic shift in the position of the center of distribution and bulk of the biomass of Pacific sardine in the California Current system (Rodríguez-Sánchez et al. 2002) has been suggested. Such a shift could hypothetically increase the isolation of the sardine population inside the gulf.

The primary purpose of this paper is to describe the sardine distribution around the tip of the peninsula, a region where the interchange or mixing of individuals from these two neighboring areas occurs. We discuss these events as related to the interannual variability of the sea surface temperature and the advection of the California Current during the same period.

Data and methods

We used catch records of the young stages of Pacific sardine caught as live bait by tuna baitboats operating off California and Baja California, records which have been compiled by the Inter-American Tropical Tuna Commission (IATTC). Records of small pelagic fish from the IATTC database are included in 1° x 1° latitude-longitude squares and were available for 1980 to 1997.

For each square, the total annual catch for *S. caeruleus* in 'scoops' (a scoop is approximately 4.5 to 6.8 kg) and their corresponding standardized effort (in searching days) were used to estimate the annual CPUE (total annual catch/total annual effort) as a proxy of Pacific sardine abundance for each square.

To evaluate the frequency of occurrence of Pacific sardine around the tip of the peninsula, the annual abundance indices estimated for each 1° square were used for construction of annual maps for 1980 to 1997. In the same maps we also show the changes in the spatial distribution of Pacific sardine in the California Current system during this warming regime.

To explain the annual recurrence of sardine around the tip of the peninsula as a function of the interannual variability of the California Current system, we used two environmental factors; the sea surface temperature (SST) off the southern end of the peninsula and the advection of the California Current during the same period. This advection is represented here as the geographic position of the oceanographic front that results from the interaction between the "cold" California Current system and the "warm" North-equatorial Current in the mouth of the gulf during May of each year when the intensity is a maximum in the California Current and the North-equatorial Current is decreasing in intensity.

Two time-series of SST off the southern end of the Baja California peninsula were obtained from different sources; the Comprehensive Ocean Atmosphere Data Set (COADS; Mendelssohn and Roy 1996) and from AVHRR satellite images. From the COADS database we used the SST data of a coastal 2° x 2° square identified by longitude 112°West and latitude 22°North in its bottom-left corner. Geographically this is between Bahia Magdalena and Cabo Falso (Fig. 1). For this square we estimated the

mean annual cycle for 1900 to 1996 and calculated the monthly anomalies as departures from the mean monthly values. Yearly anomalies were then estimated as the average monthly anomalies for the year.

The position of the oceanographic front in the mouth of the Gulf of California was obtained by analysis of the SST - AVHRR satellite images, with a resolution of 9 km, for May of each year during 1986 to 1997. The digital SST values from three transects in the mouth of the gulf were obtained and analyzed using the software Windows Image Manager version 5.38 (Kahru, 2002). The first transect is between 1a) 110.2321°W – 22.4807°N and 1b) 108.9881°W – 23.1592°N; the second between 2a) 110.1411°W – 22.3354°N and 2b) 108.8971°W – 23.0081°N; and the third between 3a) 110.05°W – 22.19°N and 3b) 108.806°W – 22.8627°N. The three transects were of the same length (148 km) and were parallel. The last transect was drawn following line 156.7 (as well-known as line 157) of the plan for CalCOFI cruises (Californian Cooperative Oceanic Fisheries Investigations) from the coordinates at station number 20 towards the gulf (from 3a to 3b) (figure 1).

The SST values extracted from the three transects were used to estimate the average temperature during May of each year in the mouth of the gulf and to obtain an average profile of temperatures representative for May of each year from which the position of the oceanographic front will be estimated.

To show the interannual variability in the position of the front, we calculated the differences between adjacent values of SST on the average profile of each year. The maximum difference between the adjacent values of SST was considered as representative of the abrupt change of temperatures that characterizes the convergence zone of different water masses. The geographic position of the digital SST values involved in the maximum difference were used to estimate the position of the front on the average profile during May of each year.

Figure 1. Map of the southern end of the Baja California peninsula, Mexico, where the catch records of Pacific sardine between Cabo Falso and Bahia de La Paz are the main focus of this paper. The parallel lines at the tip of the peninsula shown the position of the three transects used to extract digital SST values from AVHRR satellite images. Their geographical position and length are used in figure 3 as reference marks to show the position of the oceanographic front.

Results

Sardine were recorded around the tip of the peninsula in 16 of the 18 years analyzed. The exceptions were 1992 and 1996 (figure 2). An inverse relationship was found between annual SST anomalies in the southern part of the California Current and the position of the oceanographic front (Figure 3a). When there is an increase in an annual SST anomaly value or when it is a positive anomaly, the position of the oceanographic front moves toward the Pacific; when the SST anomaly is negative or is decreasing, the position of the front moves toward the Gulf of California. In other words, when there is an increase in the intensity or advection of the "cold" California Current, there is a decrease in the intensity of the "warm" North-equatorial Current, resulting in a displacement of the front toward the gulf and a predominance of the characteristics of the California Current around the tip of the peninsula, such as a negative SST anomaly. The opposite happens when there is a decrease in the intensity of the California Current and an increase in the intensity of the North-equatorial Current.

In figure 3b, with exception of the early years of the plotted time-series, a similar inverse relationship is observed between the average SST for May of each year and the position of the oceanographic front. Because of the interannual variability of the California current system here described, we found that the sardine abundance around the tip of the Baja California peninsula decreased during warm years (i.e. 1992 and 1996) when the intensity of the California Current decreased. Additionally, the sardine abundance around the tip of the peninsula increased during years with cold conditions and when there was an increase of a southward advection of the California Current. These conditions seemingly facilitate the movement of fish between the ocean and gulf sides of the peninsula. However, the presence of sardines around the tip of the peninsula was not limited to the coldest conditions.

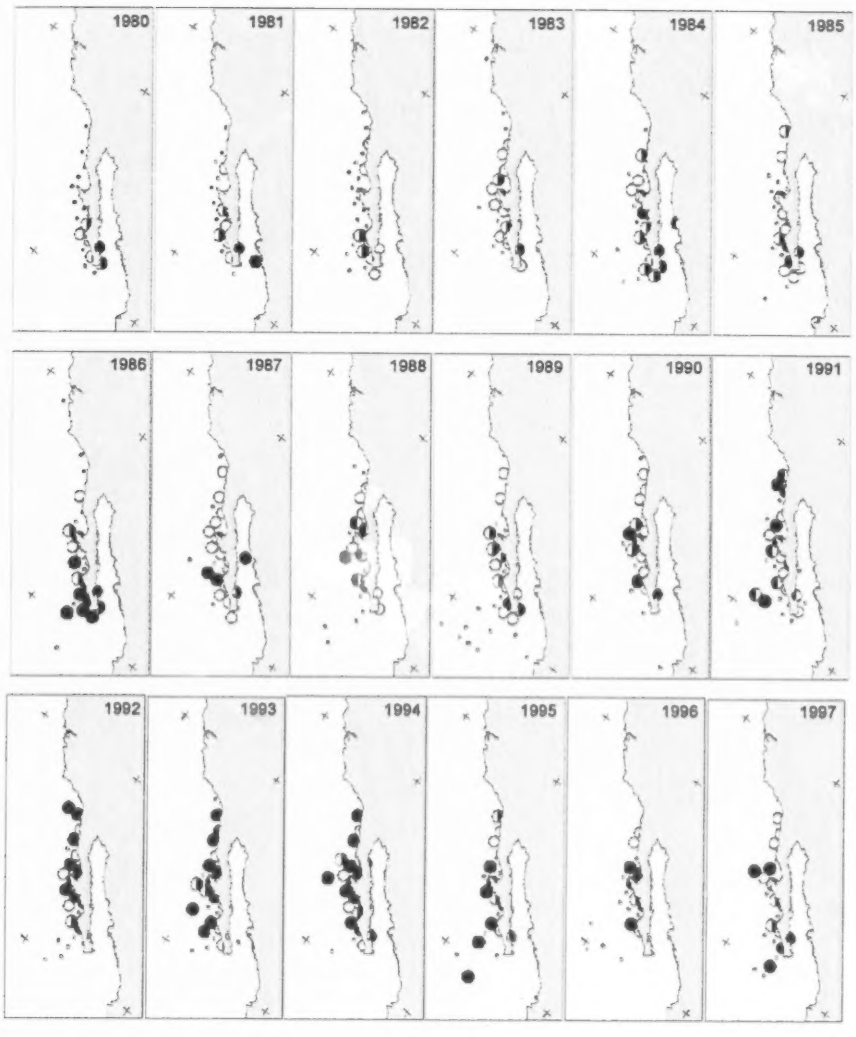

Figure 2. Annual maps showing the distribution of Pacific sardine (*Sardinops caeruleus*) along the California and Baja California coasts and around the southern end of the peninsula from 1980 to 1997. The annual abundance indices plotted in the maps are the result of total annual catch (in scoops)/total annual effort (in searching days). The indices are grouped in the intervals indicate in the base of the figure.

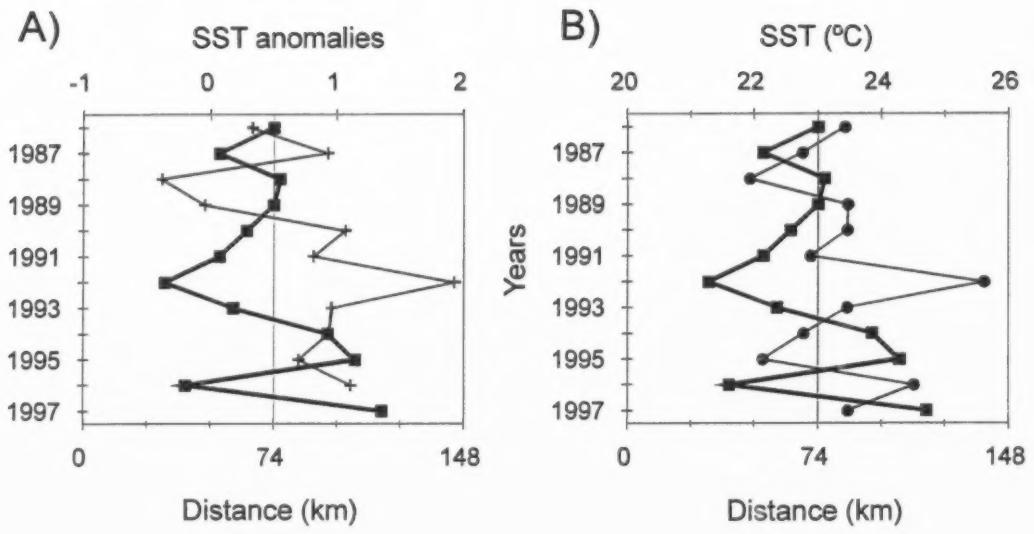

Figure 3. The interannual variation in the position of the oceanographic front during May of each year along a transect 148-km long located off the tip of the Baja California peninsula (gross line), from 1986 to 1997, plotted jointly with: a) annual SST anomalies in the Bahia Magdalena – Cabo Falso area estimated with SST information from COADS database, and b) the average SST for May of each year estimated from digital SST values of AVHRR satellite images.

Discussion

Usually, two criteria have been used for the purpose of identifying stock separation; 1) the recognition of distinctive genomes or other biological features and 2) the lack of or a significantly decreased interchange between stocks. For the first criteria, Lecomnte et al. (2004), on the basis of analyses of mitochondrial DNA, recognized a single wide-ranging population with a decline in genetic diversity on both sides of a central refuge, whereas in contrast Smith (2005) believed in semiisolated stocks along the species distribution on the basis of a review of biological features (growth rate, time of birth and recruitment, blood type, and number of vertebrae).

Our results show that the sardine stock in the Gulf of California is not isolated from those along the west coast because of the occurrence of sardine schools around the tip of the peninsula, which was formerly regarded as a physical barrier.

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ECOSYSTEM-BASED CONSERVATION AND MANAGEMENT OF PACIFIC SARDINE FISHERIES: LINKING THE ENVIRONMENT, ECOLOGY AND ECONOMICS OF THE CALIFORNIA CURRENT ECOSYSTEM

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Abstract

Besides being the target species of a directed fishery, Pacific sardine are a major constituent of the forage base of many other commercially and recreationally important species found in the California current ecosystem (CCE). Therefore, the linked environmental, ecological and economic impacts of a change in the abundance and distribution of sardines may be much more profound when changes in the predator assemblages that constitute higher trophic level fish, birds and mammals are taken into consideration. To gain some insights in this regard, we analyzed historic landings data from California fisheries and a corresponding ocean time series representing CCE-wide environmental variation to investigate how a climate-sardine regime shift might affect the structure of the CCE fisheries and recreational activities. The California commercial fish landings data indicate that as the environment becomes unfavorable for sardine they seem to be replaced in the southern CCE by jack mackerel, northern anchovy and market squid which become important forage species. Environmental signals portend ecosystem changes which are likely to alter the species compositions of commercial landings and of recreational harvests. This suggests that ecosystem-based fisheries conservation and management can be greatly enhanced by modeling and monitoring decadal scale changes in biological and physical indices.

Summary

Pacific sardine constitute the forage base for many commercially and recreationally important species found in the California current ecosystem (CCE), in addition to providing a valuable commercial harvest. Consequently, the impact of large fluctuations in the availability and distribution of sardines is a concern for higher trophic-level fisheries, linked ecological and economic systems and recreational activities as well as for the directed fishery. Changes in the abundance and distribution of sardines will be profound and far-reaching when this range of factors is considered.

To gain some insights in this regard, we analyzed historic landings data from California fisheries and a corresponding ocean temperature time series to investigate how a climate-sardine regime shift might affect the structure of the commercial fisheries of the CCE. The California commercial fish landings data indicated that as the environment became unfavorable for sardine, northern anchovy and market squid became much more plentiful in the commercial landings and probably as the predominant forage species. There were also noteworthy changes in the composition of higher trophic level

species in the commercial and recreational landings, and related changes in aggregate exvessel revenues. Modifications to existing fishing operations in order to target different species would have likely affected industry costs. These factors are needed in economic analysis of climate-sardine regime shifts on the commercial fishing industry and the consumers it serves.

Pacific sardine are also the primary prey for many marine mammals and seabirds, as well as numerous, less conspicuous species. A change in the availability of sardine may affect the distributions and population levels of these predators, which may be key in the maintenance of a robust ecosystem. These ecological relationships can have significant implications in terms of the economic benefits provided by these predator species, particularly with regard to the increasing importance of the non-consumptive use and nonuse[1] benefits they impart

From an ecosystem-based management perspective all the economic benefits predatory creatures provide must be taken into account when evaluating the total economic impact of a climate-sardine regime shift. The economic benefits society derives from sardine as forage for marine mammals, birds and fish need to be balanced against the economic benefits from harvesting sardines to determine socially optimal harvest (forage) levels. All other factors being equal, The socially optimal harvest (forage) level is that which would provide quantities of sardine for commercial harvests and for forage that equates the respective net economic benefits from each use at the margin (Figure 1) This will require information on the value of harvesting sardine for various consumptive uses (bait, human consumption, aquafeeds, etc.) and their non-extractive value as natural forage and from other non-commercial purposes. At this time, methods of assembling these data are being developed.

California commercial fish landings data indicate that environmental signals can predict, by persistence of low frequency changes, ecosystem shifts which will alter species compositions of commercial landings and of recreational harvests. This suggests that ecosystem-based fisheries conservation and management can be greatly enhanced by modeling and monitoring decadal scale changes in biological and physical indices. Extrapolation of decadal scale signals in sardine landings will then allow prediction of the rise and fall of fisheries and value added by fisheries to local economies. A comprehensive environmental-ecological-economic-based sardine conservation and management based analytical approach would also bring estimations of the sardine's total economic value.

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[1] Non-consumptive use values occur in the case where one person's enjoyment does not prevent others from enjoying the same resource (e.g. my viewing of wildlife does not prevent others from enjoying the same resource). Nonuse value is also described as *"existence value,"* the value conferred by humans on an environmental resource even though there is no personal interaction with it. An environmental resource may be valuable simply because one is pleased to know that it exists. These values are not directly observable through market prices and therefore have to be estimated using non-market valuation methods.

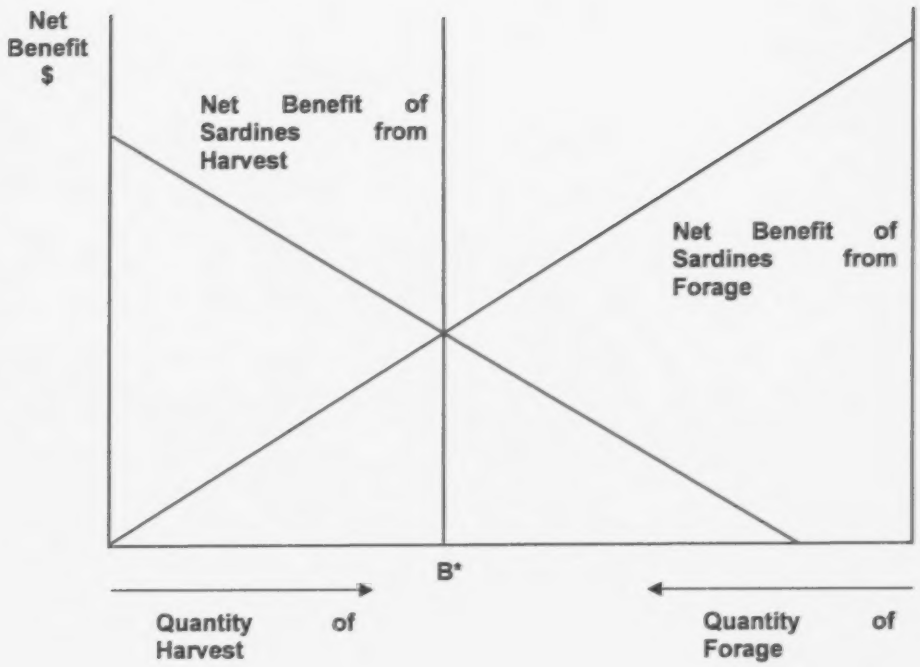

Figure 1. The socially optimal sardine harvest level. The vertical axis is net value in dollars from the sardine biomass as forage or as landings along the horizontal axis. Harvesting will occur as long as the net benefit from harvesting is greater than that from forage, and the converse. Hence, the social optimum occurs where the respective net benefit curves intersect, a harvest level of B*. The slopes of the net benefit curves will vary depending on net harvest value of the fish and the net non-market value of providing forage for predators, both of which would be affected by climate change.

Poster:

CAN OTOLITH TRACE-ELEMENT CHEMISTRY BE USED TO DELINEATE SARDINE STOCKS?

Emmanis Dorval, Barbara Javor, Larry Robertson, and Russ Vetter

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A fundamental assumption of otolith chemistry is that their calcium carbonate matrix is metabolically inert, thus once deposited the concentration of elements will not change. Delineating stocks using this technique is also more suitable for elements that are not influenced by growth rate. We conducted a laboratory experiment to evaluate the validity of using sardine otolith chemistry to identify stock structure of Pacific sardines. We generated differential growth rates by feeding wild-caught juvenile sardines on three diets: frozen copepods, commercial pellets [a mixed, balanced diet], and frozen squid [largely protein and glycogen diet). Growth rate was highest for the pellet, intermediate for copepod, and lowest for the squid treatment. Using solution-based Inductively Coupled Plasma-Mass spectrometry we compared otolith concentration in [Mg/Ca], [P/Ca], [Mn/Ca], [Ba/Ca], and [Sr/Ca] between the three diets. [Mn/Ca], [Ba/Ca], and [Sr/Ca] were relatively constant over time with little effect of diets and growth. However [Mg/Ca] and [P/Ca] varied significantly with these factors, indicating potential growth effects. In this poster we will discuss the implications of growth rate effects on the use of otolith chemistry for stock identification, in relation to the ecological factors that most likely affect sardine populations in their natural environment.

Can otolith trace-element chemistry be used to delineate sardine stocks?

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Introduction

We are validating the use of otolith chemistry to quantify age- and habitat-specific survivorship for Pacific sardines (*Sardinops sagax*). Otolith chemistry reveals retrospective habitat use because it is correlated to water chemistry at the time and location of otolith material deposition. However, both laboratory experiments and field observations are needed to ascertain which elements are most suitable to delineate stocks, before this method can be integrated into future stock assessment.

Objective

Evaluate the validity of using sardine trace-element chemistry to

- Identify stock structure of Pacific sardines
- Quantify mixing rates between sardine populations,

by assessing the effect of food source and growth rate on otolith trace-element chemistry.

Methods

- We collected juvenile fish (**A**) in San Diego Bay
- We acclimated these juveniles in laboratory for 1 month (**B**)
- We distributed these fish (**B**) into replicated tanks and fed them for 5 months with three different diets:

C1, C3

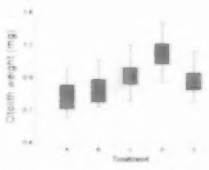
P2, P5

S4, S6

- We measured trace-element concentrations in solution of otoliths using a Sector Field Inductively Coupled Plasma-Mass Spectrometer.

Results

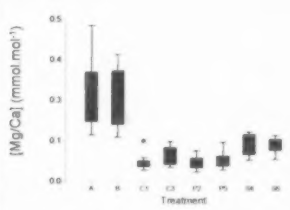
Growth patterns



Pellet fed tanks had the fastest growing fish (hence otoliths), whereas otoliths from the copepod and the squid treatments showed little growth during the experiment.

Results

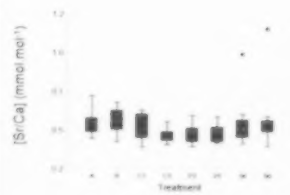
Trace elements



[Mg/Ca] ratios measured in wild caught fish (**A**) and in fish maintained in the laboratory for 1 month (**B**) were different from ratios in otoliths of fish fed on the 3 diets.

There was no significant difference between **[Mg/Ca]** ratios among diets, suggesting that **most of the difference observed from wild-caught fish was due to growth** during the laboratory experiment.

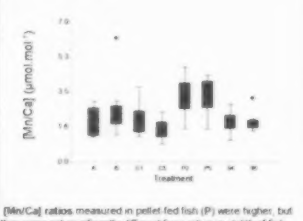
Pacific Sardine (**Sardinops sagax**)



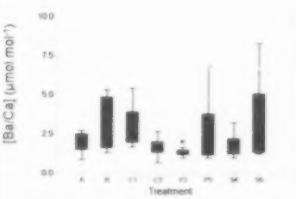
[Sr/Ca] ratios in wild-caught (**A**) fish and in fish maintained in the laboratory for 1 month (**B**) were not significantly different from ratios in otoliths of fish fed on the 3 diets. These results suggest that both **diet and growth rate may have little effect on the [Sr/Ca] ratios** in sardine otoliths.

Results

Trace elements



[Mn/Ca] ratios measured in pellet-fed fish (**P**) were higher, but they were not significantly different from ratios in otolith of fish from the three other treatments.



Within treatment variability of **[Ba/Ca] ratios** in fish fed with the three diets was high. Because there was no significant difference in growth between tanks for a given diet, we could not explain this among of variability.

Conclusions

- Mg may be labile in the otoliths of juvenile sardines, thus this element may not be suitable for studying population structure of sardines. We are designing a new experiment to test this hypotheses.
- Growth rate and diet showed little effect on sardine otolith chemistry of [Sr/Ca] and [Mn/Ca]. These elements may be useful to delineate stocks of Pacific sardines.
- More studies need to be conducted to understand the behavior of Ba/Ca in sardine otoliths, relatively to food source and growth rate.

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